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FUNCTIONAL RELATIONS AND MATHEMATICAL TRAINING.[1]

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"It is not things themselves," says Henri Poincare, "that science can reach, as the naive dogmatists think, but only the relations of things." The outstanding problems of modern science in things quantitative are indeed problems of mutual dependence and relationships. In his groping after the truth the scientist begins with measurement, when measurement is possible, then with the compilation of data, and finally the study of the relationship between the associated quantities. Thus the study and investigation of the quantitative relationships form the underlying principle of understanding the laws of nature. They enable man to know the material world in which he lives. They enter into every phase of the life of every thinking man. In fact life is made up of relationships; relationships which unite the individual in a definite manner to the society, or the group of individuals, of which he is a part; to the inorganic world and the processes of nature upon which he depends for subsistence; and to the other organisms with whom he inhabits the earth.

Furthermore, the whole process of thinking is based upon, and in terms of, certain acquired relationships which form the background or the apperceptive mass of the individual. His ability to investigate, interpret, and comprehend, or even appreciate new relationships, depends in a large extent on the knowledge of quantitative relationships already in his possession. These constitute his mental capacity. Now the true purpose of general education is to endow the individual with methods of thinking. These methods of thinking are acquired only after

[1]Read at the Educational Conference of the Academies and High Schools in Cooperation with the University of Chicago, May 8, 1926.

passing through a long series of experiences, and after undergoing a long period of training. Similarly, the habit of relationship or functional thinking is acquired only through a long and slow process of experiencing with simple relations, and with specific instances, each instance shedding some light on the exact nature of the more general relationship.

Because of the universality of quantitative relationships, the habit of functional thinking is of utmost importance to the individual. Its acquisition should be the emphasized goal of every course dealing directly or indirectly with relations between things or processes. In its preliminary report on "the Reorganization of the First Courses in Secondary School Mathematics," the National Committee on Mathematical Requirements specified that "the primary purpose of the teaching of mathematics should be to develop those powers of understanding and analyzing relations of quantity and of space which are necessary to a better appreciation of the progress of civilization and a better understanding of life and of the universe about us, and to develop those habits of thinking which will make these powers effective in the life of the individual." Thus in the realization of the value of the formation of the functional thinking habit and its inculcation in the individual lies the true purpose or usefulness of mathematics. But as Professor Hedrick[2] points out, the danger lies in the fact that those who have acquired the habit may underestimate the value of training in its formation, and overlook to emphasize the essential significance of relations, because they seem to be obvious and self-explanatory. How often in working with algebraic processes, the pupil is left alone to see the "obvious" relations, and as should be expected, the obvious is too obvious for his untrained mind to see. It will be pointed out later on in this paper that generally the text books in the secondary school mathematics fail to emphasize or bring out the significance of the relationships involved between the quantities with which they deal. "Our courses of study have failed, generally, to the present time, to give our high school pupils a grasp of functionality. Thus both the basic mathematical purpose of the course, and the foundational thinking purpose have not been fulfilled."[3]

Among the multitude of ideas and endless variety of concepts that constitute any course of study, there are a few which

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[2]Mathematics Teacher, April, 1922.

[3]Rugg-Clark, Fundamentals of High School Mathematics, p. VIII.

form its general framework. These fundamental concepts with their great organizing powers form what Professor Morrison calls the true learning products or units of the course. They are to the course what the spinal column is to a vertebrate animal, giving the whole structure its character, its stability, and its coherence. They are the unifying principles about which, as nuclei, the important materials of the course are grouped. The cellular organism in biology and the electron theory in physics are examples of such supreme and important concepts. In mathematics the one great idea which is sufficient in its scope to form the basis of unification is the function concept, "a concept which since the seventeenth century has dominated advanced mathematics, a concept which in the twentieth century, according to the auspices, will play a fundamental role in the reorganization of elementary mathematics."[4] Because of the inter-relations of the equation, the formula, the graph, and the geometric relations inductively acquired, the function concept, as Professor Felix Klein pointed out in a paper read before the International Congress of Mathematicians which met in Chicago in 1893, should be the unifying principle around which mathematical material should be organized and correlated.

"Functional relations will occur on every page of every book of mathematics, unless we suppress them," says Professor Hedrick, whose statement, because of his special investigation of, and interest in the reorganization of secondary school mathematics, may be accepted as authentic. And the significance of this statement becomes at once evident if we realize that the science of mathematics is primarily engaged in the study of quantitative relationships, both the spatial and numerical, which constitute its direct field of study, and those which are investigated and recorded by other sciences. Perhaps it is for this reason that the mathematician has claimed this fundamental and universal notion as his very own, even though its application is of utmost importance in all fields of thinking.

In its mathematical setting the term function has gone through a long process of modifications of meaning, from its original meaning as any power of a number to its present true meaning as the notion of relationships between quantities and the manner in which changes in one of the two or more related quantities produces a change in the others. The relationship is represented in

[4]E. H. Moore, The School Review, May, 1906.

terms of dependence of one variable upon another in such a way that, when one variable, the independent, is assigned any value from a set of values, called the range of the variable, the corresponding value or values of the other, the dependent variable, may be determined. The variable, such as x, in terms of which the function is defined, is simply a mathematical symbol denoting in any given discussion any one of a set of objects. In elementary mathematics this set of objects which constitutes the range of the variable consists of numerical facts. Thus any mathematical expression involving one or more variables embodies the functional relationship.

Perhaps no notion is as common and familiar to all as the dependence of one variable quantity upon another. The notion of mutual dependence and reciprocal evaluation is exemplified in every turn and feature of life and the world. For instance, the perimeter of a square depends upon the length of one side; the area of a circle upon the square of its radius; the distance travelled upon the rate and time of going; the time of vibration of a pendulum upon its length; the volume of a gas upon temperature and pressure; the cost of a railroad ticket upon the number of miles travelled; the parcel post rate upon the weight of the parcel and the distance it is sent; the amount of work a man does upon the number of hours he works; the cost of a suit of clothes upon the supply of cloth, labor, and style; the rent one pays upon the size of the house, improvements, location, and the conscience of the owner; the size of the crops upon the acreage, heat, moisture, fertility of the soil, and the industry of the farmer; the rate at which potatoes cook upon the amount of gas burned under the cooker; the sweetness of a thing upon the amount of sugar in it; the amount of light coming through a window upon the size of the window; the prosperity of a throat specialist upon the moisture of the climate; the rate of chemical change upon the amount or the mass of the substance involved; the interest on a sum of money, upon the rate and time; and so on without end.

The notion of dependence forms the basic study of all physical sciences. As soon as a science reaches the stage, in its groping after the truth, where measurement is possible, the observed data are set down and studied as special instances of some general law which it seeks to discover. Whenever possible the mathematical methods of representing dependence and showing relationships are utilized to advantage. This is especially true in physics. Every law of physics may be expressed as an equation.

Hence the necessity of cooperation between physics and algebra. It is here that we find an indispensable need for the grasp of the principle of functionality as expressed in algebraic shorthand.

"An equation is the most serious and important thing in mathematics," says Sir Oliver Lodge[5]: The concept is perhaps the oldest in mathematics, for when the rational mind of man began to count, he used the idea of equality of the things counted. The elementary algebraic equations and their solutions have been studied with various degrees of success by the ancients. The Ahmes papyrus is the oldest deciphered work treating the solution of equations in one unknown. The unknown quantity is called "hau" or "heap"[6]: Thus, "heap, its $\frac{1}{7}$, its whole, it makes 19," *i. e.* $\frac{x}{7}+x = 19$. On fragments of papyri which have been deciphered more recently, but are probably older than the work of Ahmes, statements equivalent to the system of two simultaneous equations

$$x^2+y^2 = 1000, y = \tfrac{3}{4}x$$

have been found.[7] The Greek mathematicians, as well as the Hindu, Arabian, and the European mathematicians of the Middle Ages sought numerical solutions of particular quadratic and cubic equations.

The algebraic equation interpreted rightly is a convenient method of representing the functional relationship. For example, the equation, $y = 2x+3$, determines a unique value for y corresponding to every value of x, the relation of dependence being stated in the polynomial in the right member. Furthermore the concept is not only obvious in the equation involving two variables, but is also inherent in the equation with only one variable, such as $2x+4 = 10$. For in the latter case, as Professor Young explains,[8] the problem is to find how the expression $2x+4$ varies as x varies. Among the different values of $2x+4$, that of 10 can be found, and it is but one of the many values. When the curve of the equation is drawn, the variation is at once recognized.

Mathematics had its origin in trying to solve practical problems and mathematical knowledge has grown because it has been useful. In view of the usefulness of equations in expressing physical relations compactly, the emphasis should be placed on interpreting the relations and not on the manipulation of the

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[5]Easy Mathematics, 1906, p. 127.
[6]Cajori, *A History of Mathematics*, p. 13.
[7]*Monographs on Modern Mathematics*, p. 213.
[8]*Teaching of Mathematics*, p. 387.

symbolism. There seems to be a perverted attitude on the part of the text book writers and the teachers of mathematics in neglecting the numerical relationships and in making the manipulation of the equation their primary objective. The pupil is taught how to solve a given equation, and he acquires a great deal of skill in his performance, but he has no idea what the equation stands for. He solves the equation for the value of x, and when that is done he is through, even though the equation may be a representation of relationship between two or three associated quantities, expressed in terms of a single variable x. And when he comes to verbal problems, he is told to study the relations between the parts of the problem and express them in algebraic form, and then solve the equation. But he sees no relations, for his attention has not been called to any relations in an equation. Give him the equation, he will solve it; but to set up the equation, that is another story.

An analysis, by the writer, of the text books of elementary algebra, and of the general mathematics for the junior high schools, in connection with this problem, has shown that the equation is invariably defined as a statement of equality between two numbers, and to emphasize the equality, the equation is thought of as a balance. What is done to one side must be done to the other side, if the balance is to be preserved. It is true that this statement inherently means, a change produced in one member of the equation necessitates a corresponding change in the other; but this latter meaning should be made clear because it brings out the idea of dependence and relationship. Now a formula because of its nature would be expected to state explicitly the relationship between the quantities which it symbolically represents. But a formula is commonly defined as "an abbreviated rule." Where is the relationship? The pupil is expected to get it from the nature of the problem. He does not. He tries to remember the rule. There is no relation specified, and if his attention is not called to it, he does not see it. Many writers will warn the pupil that a formula is always an equation, but an equation is not always a formula. If defined on the basis of relationship and dependence of quantities there may be some justification for this attitude, since the relations expressed in most equations are artificial and not real and practical as those expressed by the formula. But they do not always define an equation in terms of any relationship. Then, why try to confuse the mind of the child? Since his attention is not called to any

relations involved, and he cannot be expected to distinguish between an equation and a formula on the basis of any relationship, how is he to know when an equation is a formula and when it is not a formula. Is it a wonder, then, that he can solve equations involving x, y, z, a, b, c, but gets stuck on those having m, d, v, t, f, a? If an equation is defined and interpreted correctly, this apparent confusion disappears. Many writers[9] use the two terms synonymously, and they define an equation correctly as a method of representing relations between numerical facts. $X = 4y$ and $p = 4s$ both show that the perimeter of the square is directly proportional to the side.

When in connection with the solution and the application of the equation the idea of the functional relation which it represents is duly emphasized and illustrated with numerous concrete examples, algebra will become a homogeneous subject grouped about the equation as the central notion; and will not consist as at present, as Professor Bliss expresses it,[10] of "topics, related perhaps inherently, but with no indicated relationship, following each other in a confusion of radicals, exponents, progressions, imaginaries, probabilities, and other algebraic conceptions, in a way which must tend to develop a very disjointed understanding on the part of the beginner." Some text books of general and unified mathematics in the secondary schools, especially in the junior high school mathematics, have introduced the algebraic material as a homogeneous unit centered about the equation. The closer the connection between the equation and the function concept, the more uniform and coherent is the unit.

The concept of relationship can be acquired by the pupil in proportion as the teacher calls his attention to it in every case where relation exists between the quantities with which he works. But it cannot be taught or learned, if the teacher fails to interpret the equation as representing relations, and waits until nearly the end of the course when he devotes a few days to variation and proportion. Furthermore, the pupil's acquaintance with function should not consist of drawing a few perfunctory functional graphs. The acquisition of the concept must start from the very beginning, when the pupil is introduced to the simple linear equation in one variable, and continue as long as he works with algebraic expressions; with special emphasis and amplification on dependence and variation as expressed by propor-

[9]For example see Breslich: Junior Mathematics, Book I.
[10]Monographs on Modern Mathematics, p. 264.

tion; substitution, which means the calculation of one quantity in terms of another; tabulation, which actually states in full the value of one quantity in terms of another; and graphic representation of related facts.

The functional relation is often more explicitly stated in formulas expressing physical or geometrical laws. For the most part a clear understanding of these laws is reached through the study of special instances of the variation between the variables, in the form of equal ratios of the measured magnitudes. The ratios determined, the law is stated by indicating how one quantity varies with the other, directly or inversely. Proportion is thus conceived of as a special instance of variation and of the functional relationship of the form $y = kx$. The dependence or variation may be direct, that is, both variables increase or decrease in value together, as is the case when the expression has the form $y = kx$; or one quantity may vary inversely as the other, that is, one variable increases in value while the other decreases, which case has the form $xy = k$. The two special instances of the former case give rise to the proportion $\frac{y_1}{x_1} = \frac{y_2}{x_2}$, while those of the latter case give the proportion $\frac{y_1}{x_2} = \frac{y_2}{x_1}$.

Thus many problems in physics, chemistry, general science, domestic science, astronomy, as well as in mathematics, may be solved by either variation or proportion. And since the whole theory of proportion is involved in variation, this fact should be made obvious to the pupil. He should clearly recognize the relation between variation and proportion. Proportion should mean more to him than "the product of the means equals the product of the extremes." An understanding of the true nature of proportion will enable him to interpret and appreciate the various possibilities which occur in the relations expressed by proportion. The untrained mind cannot think of such relations readily, as shown by Sir Oliver Lodge in his book, "Easy Mathematics, Principally Arithmetic." He points out that most persons will attempt to use proportion in cases to which it is not adapted, and when the relations are impossible and ridiculous, as in the following: "If a camel can go without water for ten days after drinking fifteen gallons, how long could he go if he drank one hundred gallons?" "If a boy can slide eighteen feet on the ice with a running start of twenty feet, how far could he slide after running half a mile?"

As intimated above, the study of functional relations, and functional thinking are useful even in branches of thought where precise mathematical formulation is impossible. In this case the observed facts are tabulated and the data may be studied to interpret the relations between the quantities they represent. Tabulation and interpretation of tabular relations is of significant importance, not only for its own direct and practical application, but also because of its direct bearing on formulation, when formulation is possible, and graphic representation. ¶A table is strictly functional in character. It states the value of one of two related quantities when the other is given. For example, consider the accompanying table, in which the numbers in the first row represent hours of the day, and the numbers in the second, the corresponding temperatures. The table sets up a definite correspondence between the numbers representing

Hours	8	9	10	11	12	1	2	3	4	5	6	7	8
Temperatures	62	63	67	75	80	82	83	81	79	74	73	67	59

hours and the numbers representing temperature, such that whenever a certain hour is selected a corresponding temperature is uniquely determined. It should be noted that the functional relation here is not expressible as an algebraic equation.

Tables of statistics furnish useful information collected through a great number of observations, about the weather, the growth of population, crop productions and prices, the cost of living, the death rate, etc. The facts found in most statistical tables are not expressible in exact mathematical laws, or formulas, though such a formula would be of immense value. Such, for example, if a formula could be deduced by means of which the rainfall or the temperature for any specified time could be computed in advance. Nevertheless, the study of statistical tables warrants fairly safe and useful conclusions.

The functional character of the tabular representation should be emphasized, because the ability acquired by the pupil is an essential tool which may be used to advantage in other courses and in life; also because of its importance in connection with the graphical representation of relationships.

The graphical representation of numerical facts and relationships by means of geometric line segments and curves is of utmost importance in mathematics, and at the same time is very interesting to the child. The notion is not altogether new to him for he has become familiar with it in the newspapers and maga-

zines. The principles underlying this representation are easily understood and are tacitly assumed without much difficulty. As a method of representing statistical facts the graphic method has many advantages over the tabular method, in comparison of different tables of facts, in bringing out more clearly the meaning of the numerical facts and the relation between them at a glance, in showing the maxima and minima, the range of change, etc. Furthermore, as in the case of the continuous graph, this method furnishes additional facts not stated in the table.

A common method of representing statistical data is by means of the bar graph. This is supplementary to the tabular. The facts in the accompanying table are interpreted more readily by means of the diagram using line segments for numerical facts.

Months....	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Av. daily hours...	6.5	5.3	.4.2	2.5	1.9	1.5	1.7	2.2	3	5	6.1	6.8

The table states the number of electric light units used in the average residence in a certain city for each month of the year. To represent these facts graphically squared (centimeter) paper is used. A horizontal line is used for the base line on which the months of the year are marked off, the number of corresponding hours are represented by means of vertical line segments. The selection of the unit for the length of the line segments and the distance between two successive bars and their width being optional and depending on the nature of the numerical facts in the table. It should be noted that this type of work is really interesting to the pupil and develops initiative and independent thinking, for example, in the selection of the base line, the unit, etc.

After the pupil has learned to make and read the bar graph he is naturally led to the next step in the graphic representation, namely, the continuous line graph, by joining the end points of the bars. The bars are then entirely omitted, leaving only the end points. The line graph is used to represent related facts, and it not only illustrates given facts and enables comparison, but also provides additional information not contained in the table. It also paves the way for the representation of algebraic expressions by means of the geometric lines and curves. For he becomes familiar with the relation between points and pairs of values which is the underlying principle of the method of analytic geometry. The continuous line graph is best used for representing changing prices of a commodity, temperature, stock fluctuations, etc.

The graph is a powerful instrument in representing relationships admitting mathematical expressions both in their interpretations and their solutions. It is here that we see a true fusion of the geometric and the algebraic methods. Though the properties of the simple geometric curves have been known from the earliest times little use was made of them in interpreting algebraic expressions. In fact these two branches of mathematics were studied separately following two parallel lines of development, and they were jealously kept separated until in the seventeenth century the great philosopher and mathematician Des Cartes prepared the way for the union of the algebraic function concept with the geometric curve notion. The method consists of putting the points in the plane into a one-to-one correspondence with the pairs of real numbers. The position of any point may be uniquely determined by its distances from two fixed lines called the coordinate axes. The geometric curve is then thought of as generated by a moving point and its study reduces to the study of the variation of the coordinates of the points. This variation of the coordinates for most curves may be represented in an algebraic form, that is the ordinate y is expressed in terms of the abscissa x by means of a formula or equation. The graph becomes the picture of the algebraic formula $y = f(x)$, and the functional relation expressed by the equation is made obvious by the graph.

In the secondary school mathematics the formulas and equations studied are for the most part linear and quadratic functions, consequently the straight line and the parabolic graphs are of special interest. In the case of the linear equations the straight line graph always intersects the x-axis in one and only one point, except in the special case when the graph is parallel to the x-axis, and the point of intersection gives the real solution of the equation. The graph of the quadratic equations on the other hand intersects the x-axis in two, one, or no points, giving two real distinct, two real equal, or two imaginary roots of the quadratic equation. We thus see that in connection with the representation of dependence the graph may also be used in solving equations.

Thus interpreted correctly the real work of algebra consists of the study of relationships between numerical facts. The real criterion, then, should not be the number of symbols it contains, but whether there is any question of variation and dependence involved. The emphasis should not be placed on the sym-

bols or their manipulation, for symbols are only the shorthand for representation of relations. The shorthand is essential but it is not algebra. Algebra has been, and may be studied without the shorthand. To spend all the time on the shorthand, without any realization of the relationships for which the shorthand is to be the hand-maid is "to spread a feast without any guests."

Turning to geometry we find the relations involved are those existing between geometric or spatial quantities, as distinguished from the algebraic relationships between numerical quantities. The points, lines, planes, and solids which constitute the material of geometric study are related in certain definite ways. The relations existing between the parts of a triangle have been completely developed and their functional character recognized by the terminology applied to them, namely, trigonometric functions. The parts of all geometric figures are inter-related. Certain definite relations exist between the angles and the sides of polygons. For example, in the triangle, the fundamental relation $x^\circ+y^\circ+z^\circ = 180^\circ$ existing between the three interior angles, gives rise to the variations: $x = 180-y-z$, $y = 180-z-x$, and $z = 180-x-y$. Besides the trigonometric ratios, there is the relation between the squares of the side opposite an acute, right, or obtuse angle, and of the other two sides. If the functional character of this relation is recognized, it would not be divided into three separate and unrelated theorems. Functional thinking in geometry necessitates reasoning by the Principle of Continuity to discover the general relation, and applying it to the special cases. For example, the four separate theorems concerning the measurement of the angle included between two intersecting lines, in terms of the intercepted arcs of the circle, become but one general theorem, each special case depending on the location of the point of intersection of the lines with respect to the circle. Similar conclusions apply to the relations between similarity, congruence, and equivalence of plane figures.

As in algebra so in geometry, the proper emphasis is often placed not on the quantitative relationships which constitute the real geometry, but on the formal logic which is an instrument used in the study of those relationships, and in discovering other relationships from the existing ones. Our traditional courses in geometry have become so absorbed in the formal logic in the proofs of the theorems, that the functional relation is neglected and often not recognized. Studied this way geometry

fails to be of practical value in the interpretation of spatial relationships. It is open to question whether geometry as it is taught at the present time enables the pupil to see, for example, the changes produced in the shape of a parallelogram with the change of the angles while the sides remain fixed, or the change in the sides while the area remains fixed. To study changes produced in figures by the variation of one or more of its parts is to study real and practical geometry, and it is of utmost consequence toward a real mastery of geometric notions. Ability to think such reasonable relationships quickly and accurately should be a part of the reasonable mental equipment of all educated men and women.

In view of the importance of functional thinking in all fields of thought and investigation, and the important role it plays in mathematics, permeating all of the branches, and being represented by different forms of varying degrees of applications, we are led to believe that the practical value of mathematics to a non-mathematician lies in the development of the functional thinking habit. It is generally felt that mathematical training is indispensable in the study of other sciences, and by its devotees mathematics is designated as "the language of all sciences." Of course no one will deny the absolute importance of the number concept and the four fundamental arithmetical operations to the individual in carrying on intelligently and economically his duties of life. But how much of algebra, geometry, and trigonometry he needs in his further studies and in life is another question. Since he continues to deal with quantitative relationships throughout life, it is to be expected that the habit of functional thinking acquired in his courses in mathematics will abide through its constant use, and that of the mathematical processes learned only those which are directly associated with this habit will be retained and utilized.

The problem of finding the exact amount of mathematical training needed in special types of study and work is indeed a difficult one. Various investigations have been made by students of education in this line, but most of them consist in analyzing text books, magazines and newspapers, to determine what mathematical terms are used, and the minimum vocabulary of mathematical terms needed for a comprehensive reading of the subject matter.[11] These investigations, of course, throw but little light on the actual applications and practicabilities of mathematical concepts and processes.

[11]See Bobo's Thesis: The School of Education, The University of Chicago.

Of the algebraic work found in the use of mathematics in the industrial occupations, Florence Morgan[12] shows only ratio and proportion used in carpentry. Of the mathematics used in shop problems, equations comprise 11.1 percent, literal equations and formulas 22 percent, ratio and proportion 66.9 percent. Thus it seems that there is a predominance of formulas and proportion, the fundamental operations used are only in connection with the manipulation of the equation.

Mary O. McClusky[13] concludes that only a few simple exercises of an algebraic nature requiring an acquaintance with equations and the use of formulas are needed in home economics.

R. C. Scarf[14] points out in his thesis, "Mathematics Necessary for Reading Popular Science," that of the algebraic processes only formulas, bar, linear and circular graphs are used. He concludes that "the evidence presented shows clearly that one of the important functions of mathematics is furnishing a vocabulary for describing spatial and quantitative relationships." One may reasonably doubt if the furnishing the individual with a mathematical vocabulary alone is sufficient to enable him to interpret and appreciate spatial and quantitative relationships.

Similarly, the functional character of the practical mathematics is seen in the use of mathematics in agricultural studies, where according to H. B. Roe[15], perimeter and area formulas of polygons and circles, volume formulas, and formulas of the relationship of a right triangle are needed mostly. Problem analysis is considered of special significance.

An analysis by the writer, of some typical high school physics text books, has disclosed the following concepts and processes used: (1) formulas, (2) graphs, (3) ratio, (4) direct and inverse variation, (5) proportion, (6) geometrical constructions needed in the composition of forces, velocities, and optics, (7) trigonometric functions. With the exception of number 6, the others are the processes which we have shown to be directly involved in the function concept. The chemistry text books on the other hand use very little algebra. The chemical formula, such as $Fe_2+O_2 = Fe_2\,O_2$, is not a true algebraic equation. Some proportion is used in connection with determination of atomic weights. However, the ability of the pupil to interpret variously stated

[12]Thesis: The School of Education, The University of Chicago.
[13]Thesis: The School of Education, The University of Chicago.
[14]Thesis: The School of Education, The University of Chicago.
[15]Mathematics Teacher, January, 1922.

real relations, and to represent them symbolically, is of paramount importance in chemistry as well as in physics.

The outstanding finding of these and other studies confirms our convictions in the importance attached to a full understanding of functional relations and to the acquisition of the habit of functional thinking. Herein lies the primary function of a high school course in mathematics, and herein lies the true solution of the problem of reorganization of secondary school mathematics. The School of Education of the University of Chicago has been a center for educational experimentation for a number of years, and here the solution to the problem of mathematical reorganization has been along the lines of fusion and correlation of material. Following in Mr. Breslich's wake, many text books of general mathematics have recently appeared, which indicate a favorable and concerted effort toward a recasting of the subject matter. In many of them this reorganization consists merely of mixing algebraic and geometric material. True fusion, however, should be in the form of a "chemical compound," coherent, and based upon the inter-relations of concepts. Reorganization of material is taking place even in the traditional courses in algebra, where more practical problems are brought in and more use is made of the formula and the graphic representation.

But after all the text books are but tools in the hands of the teachers. When the teachers of mathematics themselves realize the importance of function concept, and are willing to lay stress on it as the primary and underlying principle of the course, and have constantly in mind the pupil's training in the formation of the habit of functional thinking, they will utilize this fundamental concept in making mathematics of direct value in the development of more intelligent citizenship. They will present the supreme ideas, of which mathematics is the science, as never before in their more obvious aspects to be understood and utilized by the individual for his personal use, and by the society and the state for the advancement of scientific knowledge. They will present them with such earnestness that the science which Plato called "divine"; which Goethe called "an organ of the inner higher sense"; which Novalis called "the life of the gods"; and which Sylvester called "the Music of Reason" shall be the very essence of reality, penetrating life in all its dimensions. It is this "new mathematics" which H. G. Wells describes in his "Mankind in the Making," as "a sort of supplement to language, affording a means of thought about form and quantity, and a

means of expression, more exact, compact, and ready, than ordinary language. The great body of physical sciences, a great deal of the essential facts of financial science, and the endless social and political problems, are only accessible and only thinkable to those who have had a sound training in mathematical analysis."

ATOMIC MAGNETISM.

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There is increasing evidence that the magnetic property of iron resides neither in the iron atom nor in the iron molecule, but most probably in the iron crystal. Recent experiments of W. Gerlach and O. Stern[1] are of some interest in this connection and of intense interest in their bearing on the quantum theory.

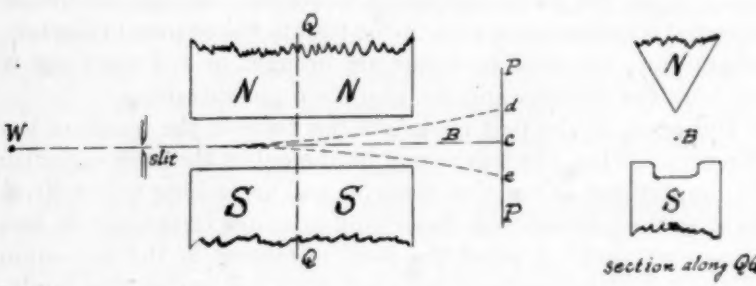

Fig. 1.

Figure 1 shows the arrangement used by Gerlach and Stern. The pole-pieces of the magnet, *N. S.* are shaped as shown so as to produce diverging lines of force in the region *B*. The whole arrangement shown in Fig. 1 was placed in a very highly exhausted chamber. A fine silver-covered platinum wire *W* is heated until the silver vaporizes very slowly, and the silver atoms which escape from *W* travel in straight lines and constitute what are called *rays of neutral atoms.* Placing a slit as shown gives a sharply defined narrow beam *B* of atom rays.

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[1]*Zeit. f. Physik* 7, 249 (1921); 8, 10 (1921); and 9, 343 and 352 (1922). *Ann. der Physik* (4), 76, 163-167 (1925).

When the magnet *NS* is not magnetized the beam *B* strikes the cold plate *P P* at the central spot *C* and gives a sharply defined deposit of metallic silver at *C*.

When the magnet *NS* is magnetized the beam *B* splits up into two beams one of which gives a sharply defined deposit of metallic silver at *d*, and the other of which gives a sharply defined deposit of metallic silver at *e*.

The two deposits *d* and *e* were found by Gerlach and Stern to be equal in density or thickness, with no trace of a silver deposit between *d* and *e* when the magnet was magnetized.

The interpretation of the above results is 1st: that the silver atoms are magnets; 2nd: that half of the silver atoms stand in the position *A* (see Figure 2) as they pass through the magnetic field, are attracted by the pole *N*, and deflected to give the deposit at *d;* and 3rd: that half of the silver atoms stand in position *D* (see Fig. 3) as they pass through the field, are repelled by the pole *N*, and deflected to give the deposit at *e*.

Copper and gold atoms are found also to be magnets, but iron atoms and lead atoms are found not to be magnets.

Fig. 2.

Fig. 3.

Now the atoms of silver must enter the magnetic field in Fig. 1 with their magnetic axes in all directions, and one would think that most of the atoms would therefore oscillate like deflected compass needles as they travel through the field. But if such oscillations existed the *mean* positions of the silver

atoms would not be as shown by A and D in Figs. 2 and 3, and there would be a diffused deposit of metallic silver between d and e in Fig. 1 when the magnet NS is magnetized. Therefore silver atoms do not oscillate like deflected compass needles as they pass through the magnetic field, they stand in positions A and D! The quantum theory which is in very close agreement with a vast array of observed facts as revealed by the spectroscope, involves the following ideas: (a) The angular momentum of a rotating atom must be an integral multiple of $h/2\pi$ where h is Planck's constant. (b) In a magnetic field the component of the angular momentum parallel to the field must be an integral multiple of $h/2\pi$. The consequence of condition (b), which is called quantization in space, is that the normal silver atom whose angular momentum is $1 \times h/2\pi$ must stand either in position A or position D, and it cannot oscillate like a deflected compass needle; if something happens to cause an atom to turn from position D to position A, all of the work done on the atom by the field is radiated and the atom is left standing in position A; if any action tends to change an atom from position A to position D, such action is wholly without effect unless the action supplies a full quantum of energy which in this case is the energy required to change the atom from position A to position D; and the most unthinkable requirement of the quantum point of view is that it involves the non-existence of any states or positions between A and D and it does not allow us to think of a change from A to D or from D to A as a thing involving time!! These are the chief paradoxes of the quantum theory and the physicist is becoming so used to them that they are beginning to seem reasonable to him! At any rate the results of Gerlach and Stern are in accord with the quantum theory point of view.

A campaign to wipe out illiteracy in five years is in progress in the Philippines. Provincial and municipal literacy boards have been organized in all parts of the island; 250,000 persons, it is said, have pledged their services as teachers; and a small textbook has been prepared which will be translated into Tagalog, Visayan, Ilocano, Bicol, and Pampango dialects to facilitate teaching. It is part of the plan to offer a prize of 1,000 pesos each year to the Province reporting the largest reduction in illiteracy.

THE NEW ELEMENTS.

By L. F. Yntema,

University of Illinois, Urbana.

The search for elements to fill the gaps in the Periodic Table of Mendelejeff has occupied the attention of chemists from the time of its first publication. Before that time, finding a new element was largely fortuitous, but the Periodic Table furnished a scheme in which every element had its place and which suggested in what natural materials an element might be found, since members of the same group or adjacent members of the same series in the Table very often occur together. Equipped with this new knowledge, science was able to assign its new discoveries to their proper positions in the Table. The classic work of Moseley[1] on the relationship of an element's atomic number and its X-ray spectrum, offered a new and exact method for classifying elements; and he showed that five elements between hydrogen, atomic number one, and uranium, atomic number ninety-two, were unknown.

The frequencies of the corresponding X-ray radiations from different elements vary as the square of the atomic number less one, or as expressed by equation: $\nu = K (N-1)^2$. Using this principle, it is possible to ascertain what elements are missing and, conversely, it is possible to calculate the approximate frequency of the radiation that a missing element should emit. When a substance is found giving that radiation, the existence of the element is assumed. Usually the X-ray spectrum of an element is excited by placing it, free or combined, on the anticathode of an X-ray tube. The radiation is analyzed by a spectrometer, which separates the beam of rays into its component parts and enables the investigator to determine the various frequencies.

Searching in minerals containing elements closely related to those that were missing, using chemical reactions and differences in solubilities of compounds as suggested by the relative positions in the Periodic Table assigned to the unknown elements and to their neighbors, and finally subjecting the product to the exact analysis of X-ray spectroscopy, chemists have been able to identify all but two, eka-caesium, an alkali metal, and eka-iodine, a halogen. First of all Coster and Hevesy[2] showed the

[1]Phil. Mag. (6) *26* 1024 (1913); (6) *27* 703 (1914).
[2]Nature, Jan. 20, 1923, p. 79.

element number seventy-two to be a homologue of zirconium, and not a member of the rare earth group, as was first suggested by Urbain.[3] Coster and Hevesy's claim to the discovery of hafnium, as they named it, has been sharply challenged by Urbain, who also published the results of an X-ray analysis of his celtium.[4] Whatever the result of the controversy may be, it remains certain that Coster and Hevesy have made important contributions to chemistry in their studies of the properties of the element, and have assigned it to its true place in the table, in group four.

A number of attempts had been made to find the missing members of group seven, eka-manganese, number forty-three, and dvi-manganese, number seventy-five, in manganese ores, but all without success. It remained for Noddack and Tacke[5] to announce that, using X-ray analysis, they found the two elements in preparations from platinum ores—chosen because the elements are closely related to the platinum metals—and in a number of other ores. They suggested the names rhenium and masurium, respectively, for their discoveries. Druce and Loring[6] showed the existence of dvi-manganese in manganese materials by X-ray spectroscopic evidence. These elements are undoubtedly very rare and consequently have been found difficult to concentrate for a study of their chemistry.

Because of their peculiar position in the classification of elements, the Periodic Table was not able to predict the number of elements in the rare earth group or what ones, if any, were missing. It remained for Moseley's work to show definitely that the number of rare earths is limited and the only one, eka-neodymium, number sixty-one, was missing. The separation of the rare earths is accomplished by fractional crystallization and fractional precipitation. From the nature of the operations, it follows that the members present in smallest amounts are most difficult to separate, and unless they announce their presence by some striking property, such as characteristic absorption bands in the visible spectrum, they may remain undetected. Because the solubilities of rare earth compounds vary so regularly with the atomic numbers, it was possible to predict quite accurately in what part of a series of fractional crystallizations

[3]C. R. *152* 141 (1911).
[4]C. R. *174* 1347 (1922); *174* 1349 (1922).
[5]Naturwiss. *26* 567 (1925).
[6]Chem. News *131* 273 (1925); *131* 337 (1925).

the missing element would concentrate. These preparations exhibited new physical properties, such as a characteristic absorption spectrum, and X-ray analysis showed the investigators, Hopkins, Harris, and Yntema[7] that the missing element, number sixty-one, illinium, was present. Here, again, the rarity of the element is such that a chemical study of its properties is yet to be made.

Loring has also suggested the possible existence of the remaining two, eka-caesium and eka-iodine, but his experimental evidence is not conclusive. It may be that both these elements are radio-active and of such short life that their detection is extremely difficult. It is to be hoped that the work of investigators who are interested in these elements may be successful, and that the list of elements, as indicated by the Periodic Table, may be soon completed.

[7]J. Amer. Chem. Soc. 48 1585 (1926).

THE DISCRIMINANT.

By Prof. Richard Morris
Rutgers University, New Brunswick, N. J.

It may be that in the opinion of some, the discriminant is a wild animal inhabiting the dense forests of algebra, seeking always (?) to devour those who by force, coercion or allurements wander through its labyrinthian mazes. This demon may have special preference for those who are entirely innocent of the algebraic by-roads and who know very little, if anything at all, of the main roads.

But when one becomes thoroughly acquainted with the discriminant, he learns that its nature is not at all ferocious. It very willingly becomes a servant. A knowledge of it makes for power, and faith in that it takes away fear. Instead of the forests of algebra being impenetrable and labyrinthian mazes, one learns that all the roads are well kept and much traveled. By following where the discriminant may lead, the mazes become illuminated highways and lead into fertile fields.

ATHLETICS NOT SERIOUSLY DETRIMENTAL TO SCHOLARSHIP.

That participation of college men in student activities need not interfere with scholarship is indicated by a comparison of averages, just completed, in Westminster College, Fulton, Mo. This shows that the average grade of all students last session was 82.69 per cent. The average of basketball letter men was 78.45 per cent, of football letter men 81.81 per cent, of baseball letter men 82.32 per cent, and of track letter men 84.34 per cent. The average of all letter men was 82.26 per cent. The average attained by the glee club, however, was 84.53 per cent, and the average of the debating team, 85.39 per cent.

A YEAR IN BIOLOGY IV.

By Harry A. Cunningham,
The University of Kansas, Lawrence.

Training in Clear and Forceful Written and Oral Expression.

The great bulk of the English composition must be gotten in a functional situation if it is to be really effective in the great majority of cases. If the above statement is true, a very great deal of it must be gotten in classes other than those in formal English. It is important that teachers of other subjects, and especially those who teach the content subjects, realize their responsibility in this matter. However, we must not think of the training which we give in oral and written composition as our contribution to the English department but, rather as an activity that is necessary for us if we are to teach biology in the way most effective for our purposes as biologists. Abundant opportunity for such training was given during the last two steps in our teaching technique—organization and recitation—and in the oral and written reports on special projects.

After our assimilation tests assured us that mastery of the unit had taken place, the class proceeded to the organization. At this stage all books, notes, etc., were put away and each pupil organized the unit, upon which he had been working for two or three weeks, in the form of a topical outline, a sentence outline, a boiled down summary in narrative form, or a syllabus. In this step the pupil was forced to gather together the material that had been used in gaining mastery of the unit and arrange it in an orderly manner, indicating which things were of greatest importance and which were of secondary importance. By the performance that came in the organization as well as that which came in the next step—the recitation—the students became much more clear headed about the unit. This step in teaching technique is of very great value.

The next and final step in our teaching technique was the recitation. We often hear the comment that high school pupils in these days cannot recite. The truth is that, under methods most generally in use, they have very little or nothing to recite about. In the daily recitation plan they have, at best, only the information which they have obtained from a few pages which have been assigned the day before. In many cases, even these few pages have not been read. But, under our plan, the

pupils came to the recitation with the understandings that they had gotten during a study period of two or three weeks. They had something to talk about. They had one of the things most necessary for clear and forceful expression—something to say. This is one condition that is very hard to obtain in the English class room. During this period the students were given the unit or some phase of it as a subject for oral discussion. Each student taught his particular topic to the class with all of his available energy and skill. During the recitation the student reciting was not disturbed. After each recitation, however, an opportunity was given for questions, corrections, and discussion. In some cases, every student was not given an opportunity to recite orally. In such a case, those who had not recited orally wrote their recitation in the form of an article. If any were not given an opportunity to recite orally at the end of one unit, these were given the first opportunity for oral recitation at the end of the next unit.

Supplementary Projects.

It was agreed at the beginning of the course that every one would do the minimum course in class. The minimum course, that all were required to master, was listed in the first article. No outside work was to be required upon the minimum course unless a student fell behind the class. No one was prohibited from working upon the minimum course but none were required to do so. The great bulk of the outside work was done upon individual supplementary projects. This gave abundant opportunity for the attainment of our fourth aim of the course; namely, intellectual independence. It also put the student in touch with a wide range of biological material and encouraged the establishment of a great number of individual intellectual interests of a biological nature. The following is a list of some of the supplementary projects worked out: 1. The Horse. 2. The Frog. 3. Mushrooms. 4. Food Values. 5. Cotton. 6. Poultry. 7. Spiders. 8. Snakes. 9. Collecting and Mounting Flowers. 10. Birds, Our Friends. 11. The Grasshoppers of Kansas. 12. Common Trees of Kansas. 13. The House Fly. 14. Wheat, A World Commodity. 15. The Chinch Bug and Its Economic Importance, 16. The San Jose Scale and Its Control. 17. Birds of the University of Kansas. 18. Game Laws. 19. Our Feathered Friends. 20. W. H. Hudson. 21. Insects Dangerous to Man. 22. The Mosquito and Its Relation

to Yellow Fever and Malaria. 23. Bees. 24. Sheep. 25. Furs and Fur Bearing Animals. 26. Luther Burbank and His Work. 27. The Sugar Industry. 28. Ants. 29. Silk: Its Source and Manufacture. 30. Tonsils and Adenoids and Their Relation to the Health of School Children. 31. The Apple. 32. Etc., etc.

The following program was followed through in each supplementary project:

1. A list of things already in mind about the unit.
2. A list of things that will have to be found out.
3. Make a bibliography.
4. Decide upon the main topics under which notes can be taken.
5. Do reading and take rough notes.
6. Make final outline for written report.
7. Written report.
8. Oral report.

By carrying out such a program and by keeping in close touch with the students in individual conferences, productions were secured that were of a high order.

The amount of individual supplementary project work done by the different members of the class of course varied. The average number of pages read for supplementary project work by each student in the upper quartile of the class was approximately 1400. The average number for each student in the lowest quartile was approximately 300. The average amount of time spent upon supplementary project work by those students in the upper quartile of the class was approximately one hour per day. These quartiles were arranged on the basis of the amount of supplementary project work done. In addition to the reading done for supplementary projects, it was determined, by counting up the references covered, that each student in the class had read at least 1200 pages in working through the units in the minimum required course. As our technique becomes better worked out, much more extensive reading will be obtained. This is enough, however, to indicate that it is possible to make a science course in high school a reading course.

Marks.

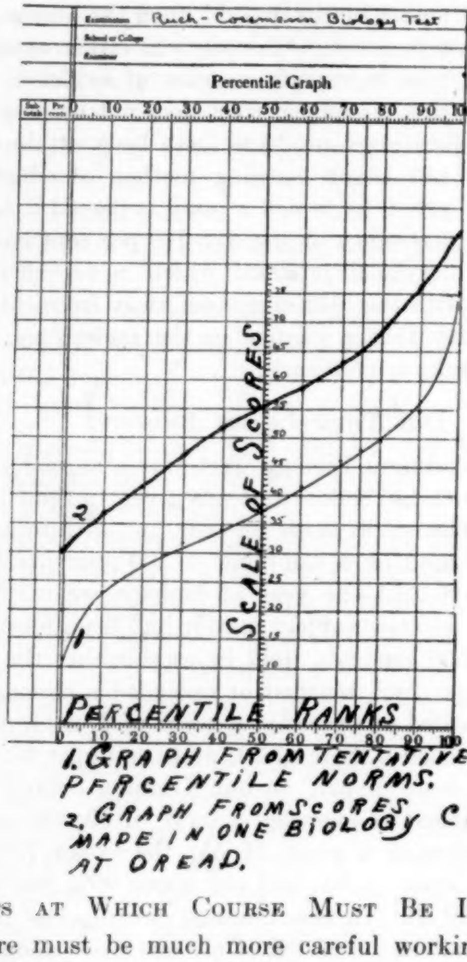
It was agreed, at the beginning of the course, that, in order to pass, the minimum required course would have to be mastered. The marking system in use at the Training School is the letter system. A means excellent; B very good; C average; D poor;

I incomplete; and F failure. Their score above passing—a D—was determined by the amount of supplementary project work done. This system is not ideal but it, at least, sets up mastery as the ideal and makes marks depend upon the amount of work done at the mastery level. All work was either acceptable or not acceptable. An increasing amount of evidence seems to indicate that getting a lesson perfect does not necessarily mean that the real educational products have been attained. If, in addition to the old lesson learning method of education, we add a marking system by which a pupil is passed if he gets his lesson only about seventy or seventy-five per cent well, we are fostering an educational program which is superficial in the extreme. It is with the idea of getting away from this inexcusable superficiality that a change in the underlying principles of awarding marks is necessary.

Did They Learn Biology?

The Ruch-Cossmann Biology Test was obtained just a few days before the end of school and was given to the class. By a comparison of the scores made on that test with tentative percentile norms based on a sampling of 500 students in biology classes who have had one year of biology, we may draw the conclusion that biology subject matter had been mastered very well. Of the 500 students used in establishing the tentative norms, the upper 25% reached or exceeded a score of 47; the upper 50% reached or exceeded a score of 37; the upper 75% reached or exceeded a score of 29; and the upper 90% reached or exceeded a score of 22. In our Training School class, the upper 25% reached or exceeded a score of 69; the upper 50% reached or exceeded a score of 55; the upper 75% reached or exceeded a score of 45; and the upper 90% reached or exceeded a score of 38. In the Training School class the highest score was 80 and the lowest 34. Only one score in our Training School class was below the median score as given in the table of tentative percentile norms. The accompanying percentile graphs shows very well the comparison between the scores made in the Training School class and those set up as tentative norms for those who have had one year of biology. These results in one class, which intelligence tests show was none above the average in intelligence, seem to indicate that mastery of subject matter can be obtained when we take as our most

immediate objectives: power to study biology; a wide range of intellectual interests in biological material; intellectual independence; and clear and forceful expression.



1. GRAPH FROM TENTATIVE PERCENTILE NORMS.
2. GRAPH FROM SCORES MADE IN ONE BIOLOGY CLASS AT OREAD.

POINTS AT WHICH COURSE MUST BE IMPROVED.

1. There must be much more careful working out of real teaching units.

2. These units must not be too long. They must be long enough to furnish a rather large amount of assimilative material and still not so long as to cause the student to lose the sense of mastery before completing the unit.

3. The number of required problems under each unit must be reduced so that some students, who master the unit quickly, will not be held on the unit solving problems in which they have lost interest.

4. Care must be used to select only that assimilative material that bears upon the unit understanding.

Outstanding Characteristics of Our Technique.

1. A clear cut statement of teaching objectives as well as curriculum objectives.
2. Attacking and mastering a unit of material directly.
3. A clear idea of what a good unit is.
4. The mastery of subject matter by aiming most immediately at the skills, abilities, and states of mind that are necessary to attain mastery in any school subject.
5. The setting up of mastery as our goal rather than 70 or 75 per cent mastery. Seventy per cent mastery means no mastery. Mastery is something which a student either has or has not.
6. The abolition of the assigned daily lesson.
7. The introduction of directed study during the assimilation period.
8. Following a definite technique in working through a unit.
9. The realization that it is poor technique to settle upon one method, such as, socialized recitation, question and answer, or developmental, and teach at all times by that method. The problem is rather to determine at just what point in our teaching technique each method can be most profitably introduced.
10. The use of tests, primarily, as a basis for teaching and not as something to be given in order that we may know whether Johnny is to pass or fail.
11. The holding of each student to strict account for the doing of his work at the very highest level of quality of which he is capable, and the holding of each student for mastery of one unit before allowing him to pass on to the next. If a student finds that the remainder of the class is passing on without him, he will try. There is no guess work as to whether a student can get by or whether he cannot. Each student knows that the only way possible for him to get by is by mastering the subject matter and he also knows that this must be done by his own efforts.
12. Basing marks upon the amount of masteries attained rather than the per cent of mastery attained. A per cent of mastery means no mastery.
13. The introduction of laboratory work only when laboratory work is necessary in the solution of a problem or when concrete evidence will make certain aspects of the course clearer.

The statement, two double periods for laboratory work each week, has been eliminated from our professional vocabulary.

In reading articles on methods of teaching, I have often felt the need of knowing the relationship of that particular article to the entire course. I have felt the need of settling upon a teaching technique based upon how children really learn science and then getting an idea just where the various methods, devices, etc., may be worked in to the best advantage. It has been with the idea of giving you a bird's-eye view of the problem, as we see it at the present writing, that these articles have been written.

HOW ATOM SHUDDER CREATES LIGHT CALLED DEEPEST MYSTERY.

One of the deepest of scientific mysteries today is the as yet completely unknown way in which the atom is able to transmute the energy of an atomic shudder into an ether or light wave of a single color. Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of Physics, Pasadena, and Nobel prize winner, has declared in lectures recently before Cornell University that the way that the atom gives off light or other radiation does not consist, as nineteenth century physicists always assumed, in the vibration of particles synchronously with the frequency of the emitted ether wave.

The physicist is now perforce obliged to forego the attempt, at least at present, to find a mechanical picture of the act of radiation," Dr. Millikan explained, "an act which, however, ejects a ray from the atom which has a definitely measurable frequency and the frequency which is a definite measure of the energy lost by the atom in the act of ejection. This energy appears at present to travel through space at least when the frequency is sufficiently high, as a vibratory dart of light."

Man is now able, thanks to science, to see the invisible, Dr. Millikan said. There has been a gradual extension in recent years of man's ability to receive and interpret ether waves which come to him outside the range in which he is endowed by nature with an organ, namely, the eye, capable of responding to ether waves at all.

"The range of frequencies to which the eye can respond is less than a single octave," he said, "and yet 100 years ago all that man had ever known of the outside world had been received through the aid of this little range of ether vibration. But beginning with the year 1881 and continuing up to within the last few months in which the higher frequency cosmic rays have been under quantity investigation, the range of man's perception has been extended, practically without breaks anywhere, through the ultra-red spectrum, the wireless wave spectrum, down to waves of infinite wave length and zero frequency, and on the other side up through the ultra violet spectrum through the X-ray spectrum, the gamma ray spectrum, and cosmic ray spectrum, up to frequencies ten million times higher than those of ordinary light. Most of our present knowledge of the sub-atomic world has come through the very recent increase in our ability to read the messages which come to us through these high frequencies."—*Science News.*

NORMS OF SCIENTIFIC ABILITY AND ACHIEVEMENT IN THE HIGH SCHOOL.

By Elliot R. Downing,
The University of Chicago, Chicago.

In a recent number of School Science and Mathematics (Vol. XXVI, p. 638 to 643) the author presented the norms for the "Group Four Test" which it is hoped may prove of use to science teachers in determining the relative abilities and achievements of individual pupils, thus disclosing those that will need most attention to prevent failures as well as those with special aptitudes for science. While such a composite test seems necessary to accomplish such a result in the case of the individual pupil it is probably unduly long for measuring the relative efficiency of the science work in various schools or systems of schools. One of the tests in the group of four tests, together called the Group Four Test, is the one given below, named the Five Word Test.

There is one word or name in each of the following groups that stands for an object or person not in the same class as the others of the group. Cross it out.

Example: Petal, stamen, pistil, ~~cotyledon~~ sepal.

1. Esophagus, pancreas, spinal cord, intestine, mouth.
2. Turnip, tomato, cucumber, peach, grape.
3. Limestone, sandstone, granite, chalk, conglomerate.
4. Eye, stomach, liver, kidney, fat.
5. Darwin, Harvey, Cuvier, Milton, Linnaeus.
6. Flood plain, dyke, oxbow, pot hole, delta.
7. Spider, clam, beetle, crayfish, centipede.
8. Lever, screw, wedge, bicycle, pulley.
9. Ptyalin, zymase, neurone, pepsin, diastase.
10. Faraday, Roentgen, DeVries, Volta, Kelvin.
11. Potassium hydroxide, ammonium chloride, calcium phosphate, sodium nitrate, iron sulphate.
12. Nymph, tadpole, angleworm, caterpillar, gosling.
13. Spirogyra, mold, club moss, bracken fern, pine.
14. Chlorine, fluorine, iodine, aniline, bromine.
15. Chromosome, chloroplast, nucleus, protoplasm, petiole.
16. Watt, ammeter, calorie, candle power, footpound.

This test it will be noticed requires not only that the pupil shall possess some information on all the customary high school sciences but also that he shall be competent in some of the mental processes that enter into scientific thinking. It seems probable therefore that it can be used as a rapid means of determining the scientific ability and achievement of large groups of students. This seems to be borne out by a comparison of the scores made on this test with those by the same pupils on the Group Four Test. The accompanying Tables I and II show the averages and the medians of the pupils in

TABLE I. AVERAGE SCORES IN PERCENTS OF STUDENTS IN SEVERAL HIGH SCHOOLS.

	No. of Pupils				Five Word Test				Group Four Test			
Schools	Fr.	So.	Ju.	Se.	Fr.	So.	Ju.	Se.	Fr.	So.	Ju.	Se.
Chicago 1	129	72	99	73	19.69	22.05	30.62	35.10	18.92	22.06	30.40	33.42
Chicago 2	142	84	78	48	21.61	27.52	27.72	37.24	19.96	19.49	26.33	38.49
Chicago 3	65	68	101	68	26.50	27.30	30.75	36.87	19.64	22.27	26.57	34.97
Chicago 4	52	22	29	27	22.96	32.95	37.92	37.93	17.99	30.61	33.56	33.41
Chicago 5	9	41	71	58	19.33	30.79	38.47	39.98	20.40	25.18	35.26	38.00
Chicago 6	143	83	50	21	18.70	27.33	36.13	36.18	17.17	23.38	29.92	36.49
All six Chicago	540	370	428	295	21.04	26.27	32.85	37.33	18.41	22.13	29.72	35.72
Toledo 1	465	209	241	100	27.00	37.09	36.44	41.50	27.09	29.87	32.98	39.24
Toledo 2	305	106	82	60	23.23	33.20	32.83	38.82	23.85	28.20	30.40	34.49
Both Toledo	770	315	323	160	25.51	35.78	35.51	40.50	25.86	29.31	32.33	37.46
All eight	1310	685	751	455	23.67	30.64	34.00	38.44	22.65	25.43	30.80	35.07

TABLE II. MEDIAN SCORES IN PERCENTS OF SAME STUDENTS.

	Five Word Test				Group Four Test			
	Fresh.	Soph.	Jun.	Sen.	Fresh.	Soph.	Jun.	Sen.
Chicago 1	19.58	20.70	27.84	33.33	16.08	21.13	30.25	32.00
Chicago 2	21.83	25.29	28.65	37.76	18.58	17.67	25.63	34.50
Chicago 3	24.31	24.11	30.08	36.88	18.75	20.83	26.50	33.37
Chicago 4	22.60	32.50	37.50	37.50	17.87	28.75	35.25	31.00
Chicago 5	17.19	30.00	37.50	38.99	19.00	25.00	32.50	36.67
Chicago 6	16.29	27.60	33.59	40.71	16.75	22.00	27.00	32.00
All six Chicago	20.50	24.47	31.62	36.61	17.00	21.00	27.87	32.70
Toledo 1	26.56	35.76	36.11	40.41	25.02	29.30	31.80	37.30
Toledo 2	22.57	32.95	31.64	37.58	22.60	27.75	27.75	32.65
Both Toledo	24.75	34.53	34.91	39.66	23.76	28.42	30.31	36.11
All eight	22.97	29.45	33.23	37.92	21.67	24.97	29.79	33.95

each of the four years in eight high schools, 3201 students in all. The accompanying graph will show at a glance the correlation between the medians of the two tests for each year in the several schools. It is evidently fairly high and is, numerically expressed, .69 for the individual schools and .89 for the two systems compared. The medians for the Five Word Test, it will be noted from the tables, are slightly higher as a rule than those for the Group Four Test.

Tables III and IV show, for each year of each school, the deviation from the average and median of all pupils. It will be noted that in all but six cases the deviation from the median has the same sign, and in four of these six if the median were changed by less than .05% the signs would agree. In the medians, and with one exception in the averages, the deviations for each year of the two school systems bear the same sign for the brief Five Word Test and for the more elaborate Group Four Test. The amounts of the deviations are reasonably close.

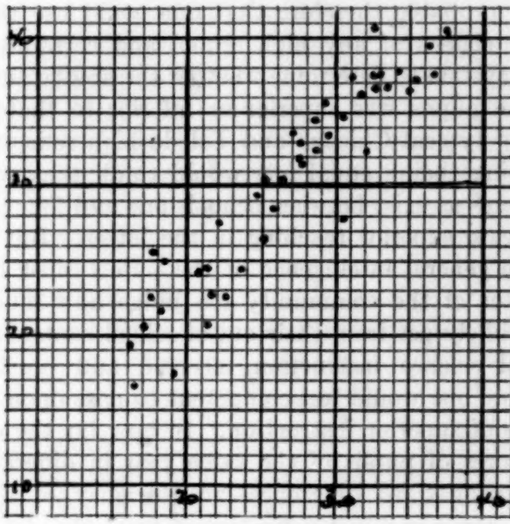


TABLE III. SHOWING THE DEVIATION OF THE AVERAGE OF THE PUPILS IN EACH SCHOOL FROM THE AVERAGE OF THE PUPILS IN ALL SCHOOLS.

	Five Word Test				Group Four Test			
	Fresh.	Soph.	Jun.	Sen.	Fresh.	Soph.	Jun.	Sen.
Chicago 1	−3.98	−7.59	−3.38	−3.34	−5.83	−3.37	−0.44	−1.65
Chicago 2	−2.06	−3.12	−6.28	−*1.20*	−2.67	−5.94	−4.51	+3.42
Chicago 3	+*2.83*	−3.34	−3.25	−1.51	−3.01	−3.16	−4.27	−0.10
Chicago 4	−0.71	+2.31	−*3.92*	−0.51	−4.66	+5.18	+2.72	−1.60
Chicago 5	−4.34	+*0.15*	+4.47	+1.54	−2.25	−0.25	+4.42	+2.93
Chicago 6	−5.97	−3.31	+*2.13*	−*2.26*	−5.48	−2.05	−0.92	+1.42
All six Chicago	−2.63	−4.37	−1.15	−*1.11*	−4.24	−3.30	−1.12	+0.65
Toledo 1	+3.33	+6.45	+2.44	+3.06	+4.44	+4.44	+2.14	+4.17
Toledo 2	−*0.44*	+2.56	−1.17	+*0.38*	+1.20	+2.77	−0.44	−0.58
Both Toledo	+1.84	+5.14	+1.51	+2.06	+3.21	+3.88	+1.49	+2.39

TABLE IV. SHOWING THE DEVIATION OF THE MEDIAN FOR THE PUPILS IN EACH SCHOOL FROM THE MEDIAN OF THE PUPILS IN ALL SCHOOLS.

	Five Word Test				Group Four Test			
	Fresh.	Soph.	Jun.	Sen.	Fresh.	Soph.	Jun.	Sen.
Chicago 1	−3.39	−8.75	−*5.39*	−4.59	−5.59	−3.84	+0.46	−1.95
Chicago 2	−1.09	−4.16	−4.58	−*0.16*	−3.09	−7.30	−4.16	+0.55
Chicago 3	+*1.34*	−5.34	−3.15	−1.04	−2.92	−4.14	−3.29	−0.58
Chicago 4	−0.37	+3.05	+4.27	−0.42	−3.80	+3.78	+5.48	−2.95
Chicago 5	−5.78	+0.55	+4.27	+1.07	−2.67	+0.03	+2.71	+2.72
Chicago 6	−6.68	−1.85	+*0.36*	+*2.79*	−4.92	−2.97	−2.79	−1.95
All six Chicago	−2.47	−4.98	−1.61	−1.31	−4.67	−3.97	−1.92	−1.25
Toledo 1	+3.59	+6.31	+2.88	+2.49	+3.35	+4.33	+2.01	+3.35
Toledo 2	−*0.40*	+3.50	−1.59	−0.34	+0.93	+2.78	−2.04	−1.30
Both Toledo	+1.78	+5.08	+1.30	+1.74	+2.09	+3.45	+0.62	+2.16

It seems probable therefore that one could use this test in the science classes of any high school and certainly in those of any city system to determine whether the ability and achievement of the pupils was superior or inferior to that displayed by pupils of typical Chicago and Toledo high schools.

Other things being equal one would think that such differences in scores as exist between schools one and four in Chicago might indicate superior teaching in the latter. But evidently the relative general intelligence of the pupils must be known, the character of the community (to judge how much science pupils will likely get from their out-of-school contacts), the pre-high school science instruction received and possibly other factors before one would feel competent to pass upon the scores as evidence of superior instruction. In how far the differences between scores of pupils of the same year in different schools can be attributed to differences in efficiency of the science instruction can possibly be discovered from the data in hand and the matter will be discussed in a later paper.

The marked difference between the scores of the Chicago schools on the whole and the Toledo high schools is likely due in large measure to the excellent work in elementary science given in the grade schools in Toledo, which is largely lacking in Chicago. The difference is most marked in the early years of the high school as if the pupils had something at Toledo which enabled them to profit by the high school science instruction, not similarly possessed by the Chicago pupils.

It takes only ten minutes or less to give the Five Word Test. The instructions are on the test. Pupils are asked to hand in their papers as soon as they are completed. The slower pupils are stimulated to be expeditious when the brighter pupils begin to turn in papers.

By cutting out of a blank test the words that should be crossed out and laying this cut-out on the paper to be scored one can count at a glance the number of words correctly marked so that ten to fifteen papers are scored a minute. Multiply the number of words correctly crossed out by $6\frac{1}{4}$ to obtain the pupil's score in percent.

The medians and averages given are based on tests given to pupils in the high school classes of the several schools at the end of the first semester in each high school year. To determine what the median should be for some other time obtain the difference between two successive medians of the

mid-years between which the date the test is given occurs. Multiply one tenth of this by the number of months between the date of the test and the nearest midyear. Add or subtract this product to the mid-year score. Thus the median for all freshmen in the table (II) is 22.97%, for sophomores 29.45%. The median for the end of the freshman year is

$$22.97\% + \left(5\times\frac{29.45\%-22.97\%}{10}\right) = 26.21\%.$$

DOUBLE MERCURY CONTACT FOR CLOCK PENDULUM.

By Paul E. Martin,

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Mercury contacts of the common type placed at the position of rest of the pendulum are continually knocking off the drops of mercury and so needs attention very often. Likewise most metal contacts corrode at the points where contact is made and therefore needs attention more or less frequently. At least these seem to be the results of the writer's experiences.

By having two cups of mercury, A and B in Fig. 1, so placed that contact is made at the end of the swing of the pendulum, one still has the advantage of the mercury contact without the disadvantage of continually losing mercury from the container. These cups, as used in this laboratory, are about ¾ inch in diameter and perhaps 3/16 inch in depth. A machine screw is securely fastened through the base of each cup, the threaded end being down. The functions of each screw is to adjust the cups vertically and to serve as a conductor from the cup to the metal base into which each is screwed. The arms "a" and "b" with the cross bar which is fastened to the clock pendulum are aluminum, with the exception of the very tips of *a* and *b* which are platinum. The metal bases are in electrical connection all the time. The external electrical circuit consisting of battery and relay (or whatever is to be used) is then completed with the seconds clock by connections to the clock works and the metal supports of the cups A and B.

Each cup is filled with mercury so that the meniscus is well above the level of the edge of the cup. The arms a and b may be adjusted laterally by pivoting on the screw that holds it to the cross bar. Best results are found by adjusting the height of the cups and the lateral position of the arms until the tip of the platinum points make contact about half way up on the side of the mercury meniscus. However the lateral adjusting should be made at least fifteen minutes before making the adjustment vertically as the pendulum takes some time to come to its steady amplitude. In this way the time of contact is not appreciably longer than those with the contact in the center of the pendulum swing.

This type has been in use in this laboratory for several months without cleaning, and has repeatedly been used for hours in a stretch without readjusting during the time used.

A KUNDT'S TUBE EXPERIMENT.

By Rolla V. Cook,
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During the summer of 1924 while experimenting at Indiana University with a Kundt's tube I discovered that the striae could be most readily observed by using pith dust in the tube.

The pith dust was obtained by grinding dry pith from sun-flower on a fine-grained emery wheel. By the use of this dust I was able to obtain discs that extended completely across the tube and having the same diameter as the inside of the tube.

These striae were obtained by the ordinary method used with a Kundt's tube, but for demonstration purposes I found the following to be an excellent way to produce them: Some pith dust was placed in a glass tube of any convenient length and diameter. In one end of the tube a stopper was placed and the open end of the tube was inserted in the open end of a sounding organ pipe. When the tube was inserted the proper distance the striae formed at regularly spaced intervals and showed the nodes and loops in an excellent way. Discs apparently but one particle in thickness were formed and when the tube was carefully adjusted with regard to distance to which it was inserted into the organ pipe the separate particles remained almost motionless. Often they wove themselves into thin sheets and when the air was turned off they fell over, maintaining the sheet form.

Also I obtained these striae by passing an electric spark across the end of a glass tube (either open or closed) into which some pith dust had been placed. The howl produced by a telephone receiver excited excellent striae in a glass tube. Some photographs of the striae were made.

Pith dust being lighter than cork dust gives striae of greater height than the latter. As it does not adhere to the tube I find its use for this purpose better than lycopodium powder.

I believe this is the first time that pith dust has ever been used for demonstrating the striae in a Kundt's tube and I gladly give this bit of information to all who may be interested in using it.

SOME NOTES ON THE INTRODUCTION TO GEOMETRY.

By J. O. Hassler,
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A great deal depends on a student's first conception of a new subject. He must be given a true notion of the nature of the subject, he should see the possibilities of practical use of the subject-matter, and he should not be plunged in over his depth. If possible, there should be a point of contact with former courses. At the beginning of geometry a student faces the problem of learning the definitions of many new terms which he is to use in the study of the subject, and he is introduced to logical proofs. For the sake of those beginners in the ranks of geometry teachers who may read this I shall discuss these two subjects in turn and then consider the use of intuitive and constructive methods in the approach to formal geometry.

The Definitions.

I remember vividly my first lesson in geometry. It consisted of several pages of formal definitions, axioms, and postulates which were to be memorized. The definitions of practically all the terms used in the first fifty pages were classified in the first dozen pages. Even the postulate of parallels was learned in the first lesson, though it was not used for some weeks afterward. A much better arrangement is found in the average modern text. Exercises and questions designed to provoke independent thought about the new terms whose definitions are being studied are interspersed with the definitions. The parallel postulate is not encountered until the time comes to take up the study of parallel lines. There are few texts, however, that do not introduce more definitions than are necessary in the beginning. For instance, why should theorem, corollary, and other such terms be introduced before we are ready to use them?

If a teacher must by force of circumstances beyond his control use a text in which the introductory pages are clogged with definitions of terms not used for many pages later in the book, he should select in the beginning only part of the definitions in the book, those whose immediate use not only justifies their introduction but emphasizes their meaning. The remaining definitions should be studied later, just when the terms defined are about to be used.

Every definition should be given a numerical illustration if

possible. The statement, "two angles whose sum is a straight-angle are called supplementary angles," can be memorized and understood as it stands, but it is more readily understood by the pupil and the meaning is made more vital if he is led to consider pairs of angles like 140° and 40°, 120° and 60°, etc., not in a list of exercises on a later page, but in connection with the definition.

After each group of related definitions there should be exercises which give the student opportunity to become acquainted with the terms just learned by using them. For example, the notion of angle is made clear and the definitions of various kinds of angles are given. Immediately following this should be groups of exercises related particularly to the facts about angles just learned. They should be such as will not only emphasize the meaning of the terms but will call forth some independent thought about them.

This list of exercises, with definitions of angles preceding it, should not be merged with the general introductory matter. It should be a distinct unit. In a similar manner should all terms necessary for immediate use be introduced. If the text does not provide this, the teacher should supplement the text.

The Introduction to Logical Proofs.

I also remember my second lesson in geometry (or was it the third?). After mastering definitions enough to carry us well into the first "book," including the definitions of "scholium," "contradictory therorem," "converse," etc., we proceeded to prove that "All straight angles are equal." One might say that having swallowed the camel of the parallel postulate we strained at the gnat of equal straight angles. Any healthy minded youth who is encouraged to think about it will be more inclined to doubt the statement that only one line can be drawn parallel to a given line through a given point outside the line than he will the statement that all straight angles are equal.

The average modern text aims to avoid this predicament of having the student impede his progress by quibbling over minor and ultra-logical technicalities. The theorems whose truths seem axiomatic are placed immediately after the axioms with little or no proof. Sometimes they are boldly listed as postulates. Why not? What shall limit the assumptions we may make at the beginning of our logical science? If our desire is to make it a perfect type of a logical science then our set of postulates must

satisfy three conditions. They must all be independent; that is, no one may be proved by means of the others; they must be non-contradictory; they must be such that they exactly define this science and no other. To attempt to make them fulfill the first condition is to limit them to the irreducible minimum and undo all efforts to make geometry comprehensible to the tenth grade youth. This is the condition we have been fighting for years. The skilled logician may do his work with but few tools, but the untrained youth needs more, hence we lay down more assumptions at the beginning. It is easy to see that the other two conditions are satisfied, even if we assume at the outset the truth of many of the preliminary theorems. Within the limits of comprehension of our students we are proceeding in the spirit of mathematical and logical development by adding these theorems to our list of postulated facts. One of Euclid's postulates was that "All right angles are equal." In some cases the preliminary theorems are called corollaries and the simple steps are suggested by which their proofs follow from the axioms and postulates just preceding.

Having avoided the possibility of dulling the pupil's interest by asking him to engage in tedious quibbling over evident truths, the usual custom is to initiate him into the mysteries of a logical demonstration by means of the superposition proofs of the congruence theorems. What an initiation! The technical details of a formal proof of the theorem, "If two triangles have two sides and the included angle of one equal to two sides and the included angle of the other, respectively, the triangles are congruent," are not the things that will give a student a proper appreciation of geometry at the outset. The necessity for some of the minor logical steps in the proof are as far removed from his comprehension as is the necessity for proving "all straight angles are equal." The proof is too long for a beginner. Having prevented the vessel from foundering on the Scylla of logical finesse, we should not let it be engulfed in the Charybdis of complexity. Let the first theorem be one with a proof involving a few simple steps each of which demands a reason for being in the proof. This congruence theorem and its dual, "If two triangles have two angles and the included side of one equal to two angles and the included side of the other, respectively, the triangles are congruent," might well be accepted (postulated) in the beginning as facts (to be proved later, after the student has

had experience in formal demonstration). A scheme like the following might be used:

After defining and classifying triangles, do the following exercises:

1. Draw a triangle with an angle of 55° (use protractor) making the two sides including the angle one inch and one and one-half inches, respectively.

2. Draw a triangle with a side one inch long, making the two angles adjacent to this side 30° and 57°, respectively.

3. Draw two triangles as follows: One has a two-inch and a three-inch side including an angle of 60° and the other a two-inch and three-inch side including an angle of 80°. Cut these triangles out and try to fit one upon the other to test their congruence.

4. Make two triangles with the following specifications and try to make them coincide: sides two and one-half and three inches with included angle 60°; sides two inches and three inches with same included angle.

5. Perform a similar experiment with two triangles, each having sides 2 inches and 3 inches long and the included angle 60° in both cases.

Which of the pairs of triangles compared in Exercises 3, 4, and 5 seem to be congruent?

6. Try fitting together two "cut out" triangles one of which you have constructed with two angles 60° and 45° having a side 2 inches long included between them and the other with angles 60° and 45° including a side one and one-half inches long.

7. Perform a similar experiment with two triangles made according to the following specifications. Angles 60° and 45° including a side 2 inches long; angles 80° and 45° including a side 2 inches long.

8. Make a similar experiment with two triangles, each having angles 80° and 45° including a side two and one half inches long.

Which of the pairs of triangles considered in Exercises 6, 7, and 8 seem to be congruent?

Assumptions about triangles. The experiments performed in Exercises 3-8 above lead us to suspect that:

A. If two triangles have two sides and the included angle of one equal, respectively, to two sides and the included angle of the other, the triangles are congruent.

B. If two triangles have two angles and the included side of one equal, respectively, to two angles and the included side of the other, the triangles are congruent.

We need the knowledge of these facts in this chapter to better acquaint us with the methods of geometry. We therefore assume for the present that they are true. They will be proved later.

After these facts are accepted there is possible for the pupil a number of simple one-step exercises applying them. Consult any good modern text for illustration as to the nature of these exercises. If the exercises are well chosen and carefully graded, the student may be led gradually up through the experience of simple deductions to an appreciation of the meaning of a proof by actually making proofs, though they may not be formally labeled as such. He can see the wonderful applications of geometry through exercises like the method of Thales in measuring the distance of a ship from the shore. All of this can be done before a pupil has had a formal introduction to the axioms and

postulates. He will then have a clearer comprehension of the necessity for and meaning of the postulates when they are presented. A teacher can easily supplement this kind of introduction to geometry if it is not provided in the text.

When we are ready to introduce our students to a formal demonstration, we should have a theorem with two particular attributes. The fact stated should seem to require proof, and the proof should be one that is easily followed, each step appealing to the pupil as being a natural and necessary thing to do. Two examples are offered here:

(1) "The bisectors of two supplementary adjacent angles are perpendicular to each other."

(2) "The angles opposite the equal sides of an isosceles triangle are equal."

Intuitive and Constructive Geometry.

By intuitive geometry is meant the study of geometric forms for the purpose of becoming acquainted with their nature by using them and experimenting with them, and consequently making conclusions as to relations existing between them which seem to be true. In such an introduction to geometry considerable use is made of the ruler and compasses, the tools of precise constructive geometry, and the protractor. In many of the modern courses in the junior high school, intuitive geometry is introduced as early as the seventh grade and continued through the eighth and ninth. If students have not had intuitive geometry preceding the usual tenth grade course in plane geometry, it is necessary to emphasize it in the introduction to the course. Three good methods of presenting it are: (1) by exercises in geometric construction, (2) by lists of thought-provoking questions and exercises, making use of the mathematical equipment (arithmetic and algebra) of the pupil to familiarize him with the forms of geometry, and (3) paper folding.

In the first reaction against the traditional method of presenting plane geometry as a strictly logical subject from the beginning, as it had been taught to college students for centuries, the "construction" method of approach was featured very much by some. Pupils used the ruler and compasses to make precise construction of perpendiculars, parallels, line-segment-bisectors, angle-bisectors, triangles with three parts given, inscribed and circumscribed circles, etc. The probable result of such an approach to geometry, unless guided by a wise teacher, is that the

pupil will assume geometry to be much like a course in mechanical drawing. Disillusionment is sure to come to him, but it is likely to come after he has "lost his step" in the course. There is a valid objection to requiring a pupil to do a great many complicated exact mathematical constructions before being able to prove them correct.

Examples of the second method of informal or "intuitive" introduction to geometry may be found in many of the most recent texts. The following exercises are given for added illustration:

1. If a basin of water is allowed to become absolutely still, what form will be taken by the surface?
2. How would you find the shortest distance from Chicago to New York?
3. How many straight lines may be drawn through three points? Through four points? Through five points?
4. How does a man proceed if he wants to set three or more posts in a straight line?

One exercise in paper folding will be given as an illustration of what may be done along that line by an ingenious teacher. Valuable material may be found in Row's *Geometric Exercises in Paper Folding*, Open Court Publishing Company, Chicago.

Let the pupil take a rectangular piece of paper and fold so that the crease (a straight line) will intersect one side of the paper, making oblique angles with it. In Fig. 1, CA represents the straight side of the paper and OB the crease. Now if OA and

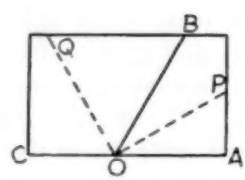

FIG. 1

OC are folded over on OB the creases made will be bisectors as is obvious by the exact coincidence of angle AOP with POB and COQ with QOB in the folded figure. Also, the folded figure shows that the angle POQ is half of the straight angle AOC. Thus the pupil discovers that the bisectors of two supplementary angles are perpendicular to each other. He has also performed, with the folded paper, steps analogous to those he must take in making a formal proof.

DIAGNOSIS AND TRAINING IN ADVANCED HIGH SCHOOL ALGEBRA.

By Robert W. Yingling,

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The following is the record of an experiment with a high school class in advanced algebra, in diagnosis of each individual student's weakness in the preparation from the first year's work in algebra and in bringing the ability of the lower or poorer students up to the level of the higher or better ones. The experiment also includes a more-or-less objective study of the comparative values of group and individual instruction.

The diagnosis was made by using the four parts of Hotz's Algebra Scales Series A, that measured the ability of the class, when they came to the advanced course at the beginning of the semester, in addition and subtraction, in multiplication and division, in equations and formulas, and in verbal problems. The four parts of Hotz's test as used were as follows:

Scale I—Addition and Subtraction.
Scale II—Multiplication and Division.
Scale III—Equations and Formulas.
Scale IV—Verbal Problems.

Each of these four scales had twelve exercises to be solved so that a perfect score on each of the four scales would be twelve. The score for each individual student in the class for each part of the test is shown in Table I. The scores made by the students

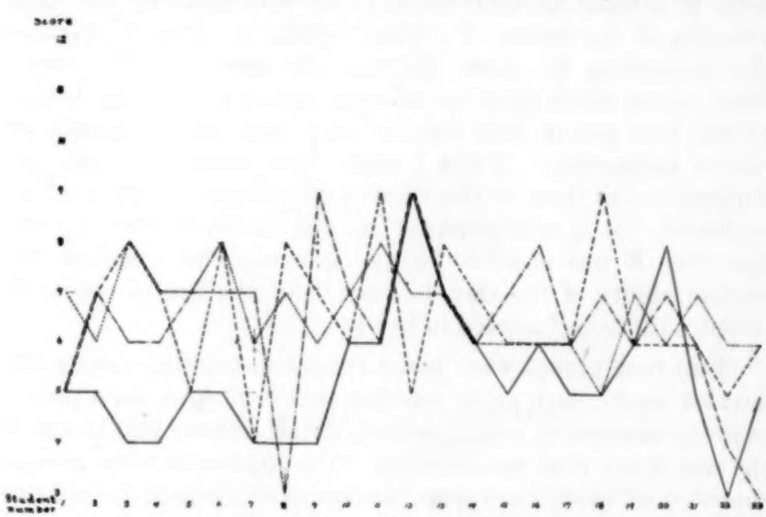

Table I showing scores of each student on all parts of 1st Test

in addition and subtraction are connected by the solid line; the scores made in multiplication and division by the broken line; the scores in equations and formulas by the dotted line; and those in verbal problems by the line composed of dots and dashes.

From this table it will be seen that (1) the composite ability of the class as a whole is very nearly the same on all parts of the test; (2) the ability of the class along one particular phase of the work, as addition and subtraction, varies from pupil to pupil; and that (3) the individual student does not have equal ability in all four phases of the work. This latter point was the basis of instruction to bring all the students as nearly as possible to the same level of ability, without too great an expenditure of time and energy.

The experiment covered a period of fifteen weeks. The first week was used for giving the first series of Hotz's tests. Those students who fell below the median of the class in Scale I of the test, that is, in addition and subtraction, were put into a group by themselves to be trained in addition and subtraction. Those who fell below median in Scale II were put into a separate group for work on multiplication and division; those who fell below median in Scale III were separated into another group; and those who fell below median in Scale IV were put into still another group. The term, median, as used here, is defined as that approximate mid-point in the rank grouping of the scores of a class, beginning with the highest and proceeding on down, in successive order, to the lowest score, above which there are as many scores as there are below. In the four groups thus formed there were 33 individuals to receive instruction. Table I shows that there were only 23 students in the class, so this total of 33 individuals needs to be explained. It is accounted for, as will readily be seen, by the fact that it was possible for any individual to be below the median ability of the class in more than one line of the work tested, thus being counted in two groups.

These four groups were given special instruction during the next six weeks, each group meeting once each week for a period of thirty minutes, in a room entirely detached from that in which the rest of the class was working. The work with these groups consisted of blackboard work on exercises dictated from first-year algebra texts. No attention was paid to the mistakes of

the individual other than that of encouraging him to correct his own errors and speed up his work so as to accomplish as much as the remainder of the group.

At the end of this six-weeks period, another set of tests was given over the four phases of algebra that were tested previously by Hotz's Series A Scales. Those students who had been working in the groups and were still below the median of the class (as shown by their scores on this second series of tests), were given individual instruction for another six weeks period in that particular phase of the work in which they still remained low. Each of these students was given practice work for a period of thirty minutes once each week, under the supervision of the instructor, attention being paid to the elimination of the mistakes that were constantly recurring in the student's work.

At the end of this second six-weeks period, a third series of tests were given. This time Hotz's Series B Scales were given with the following omission. The Series B contains on the average twice as many exercises to be worked as the Series A. All of the exercises in Series A are included in the Series B, so the latter series was given omitting those exercises that were given in Series A.

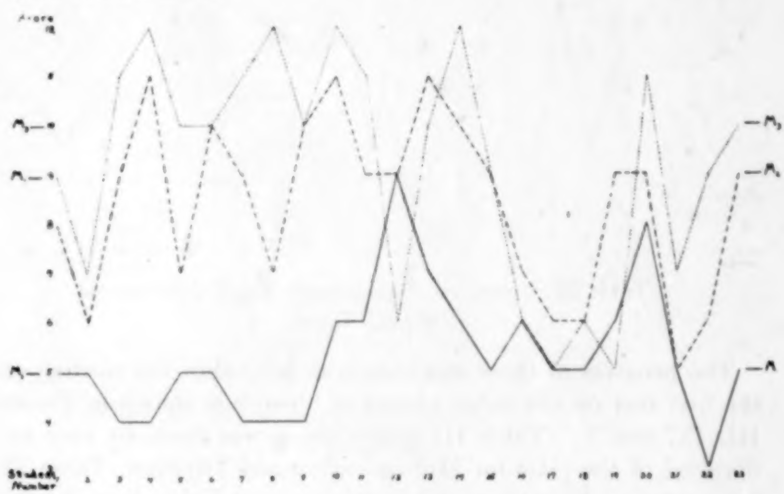

Table II Scores in Addition and Subtraction in all Three Tests

The results of all of these three sets of tests were recorded graphically in the form shown in Table II, and from these

graphs the conclusions as to the success of the experiment had to be drawn. Table II shows the scores of each individual of the class on all three tests in addition and subtraction. Students numbered 3, 4, 7, 8, 9, and 22 were the ones who received special instruction in addition and subtraction during the first six weeks. It will be noted that their scores on the first test were below the median score 5, marked M[1]. Of these six students who were below median on the first test, it will be seen that only two, students numbered 8 and 22, were below the median (M[2]) on the second test. This showed the effect of the group instruction on these students. On the third test, none of the original six students still remained below the median M[3] showing that the ability of the other two had been sufficiently increased to place them above the median ability of the class.

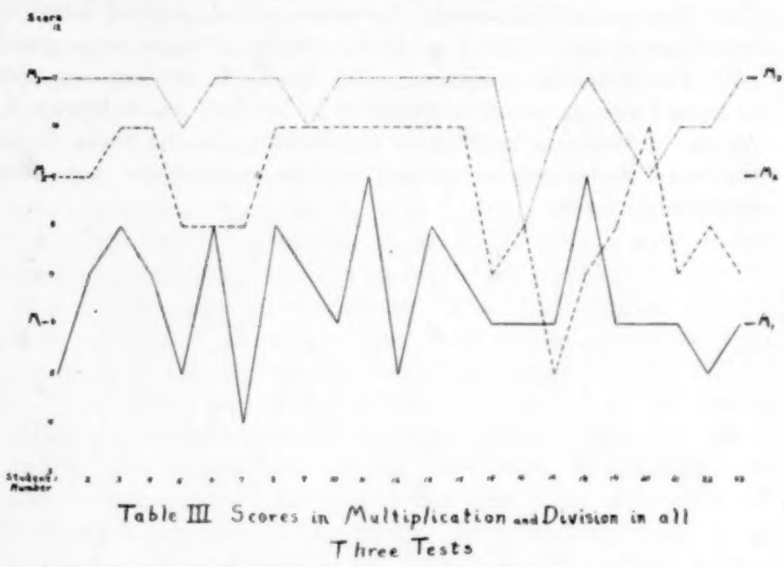

Table III Scores in Multiplication and Division in all Three Tests

The progress of those students who fell below the median on the first test on the other phases of algebra is shown in Tables III, IV, and V. Table III shows the scores made by each individual of the class on Multiplication and Division, Table IV the scores on Equations and Formulas, and Table V on Verbal Problems.

From these records, it will be seen that of the 33 who fell below the median on the first series of tests, only 15 remained below the median on the second series. In other words, 18 of these 33 progressed enough under the group instruction to

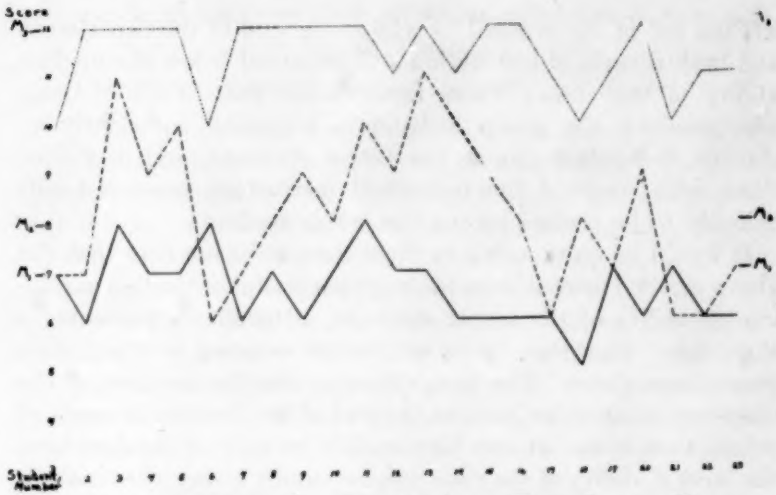

Table IV Scores in Equations and Formulas in all Three Tests

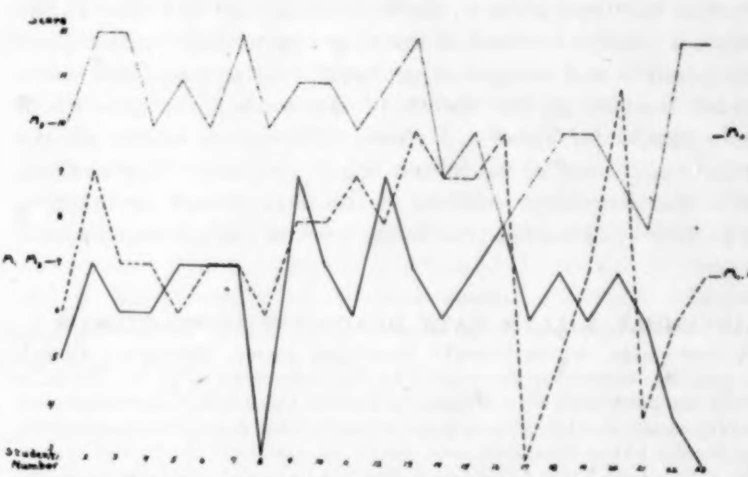

Table V Scores in Verbal Problems in all Three Tests

raise their ability above that of the median of the class and, as a result, force other *good* students below the median. On the third series of tests, 5 of the 15 remaining over for the individual instruction improved sufficiently during the second six-weeks period to raise themselves above the median of the class. This

left ten out of the original 33 who at the end of the experiment and both periods of instruction still remained below the median ability of the class. These figures show that 54.5% of those who received the group instruction improved sufficiently to classify themselves among the better students, and 33.3% of those who received the individual instruction improved sufficiently to be classed among the better students.

It would be quite unfair to draw the conclusion here that the group method proved to be the more successful of the two in raising the ability of the poorer students, although the percentages show this. However, there are factors entering in other than percentages alone. The competition among the members of the class was much more keen at the end of the fourteenth week of school than it was at any time earlier because of the fact that the level of ability of the class was constantly rising, thus making it harder for a poorer student to come up above median and force a good student down at the end of the second period than it was at the end of the first period of instruction. If the instruction had been given to the individuals first and later to the groups, a relative reversal of the above percentages might have been possible and altogether probable. As it was, there was a decided increase in the ability of the weaker students which amply repaid for time and effort, although as usual, all the students could not be made into bright students. The analysis due to the diagnostic qualities of the tests cleared up much of the possibility of wasted time in the work of the advanced course proper.

INVISIBLE KILLER EATS DEADLIEST OF BACTERIA.

Bacteriophage, which literally translated means "bacterium eater," is a puzzling something discovered by the researches of F. W. Twort, a British scientist, and F. d'Herelle, a French Canadian. Bacteriologists are very much at odds over it, some claiming that it is a living organism, or at least a living substance, and others maintaining that though it does some things that living beings do it does not have all the attributes of life.

If it has an organized body at all it must be exceedingly minute, for it has never been seen even with the ultra-microscope, and it can pass through the pores of a fine porcelain filter. Moreover, it is not killed by high temperatures that are fatal to all other known organisms. Yet when even a little of the fluid containing it is added to a culture of bacteria, the latter are soon dead, no matter how numerous they are nor how little there was of the bacteriophage to begin with.

It is this apparent power to multiply itself that sets the bacteriophage apart from even the most complex of lifeless chemicals, for lifeless things do not have the power of self-propagation. Much research on this puzzling stuff is now in progress, from which far-reaching effects in medicine and sanitation may result.—Science Service.

HOW TO ACCOMPLISH OUR AIMS IN GENERAL SCIENCE.*

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This topic presupposes that we are agreed as to what our aims in general science are. Such however is not altogether the case. One need but examine the various textbooks and courses of study or read various articles upon the subject of general science to satisfy himself on that point. We do not seem to be altogether agreed as to whether general science is to be a course made up of samples of the various sciences, and acknowledged as a "sample" course, or whether it is to be a course organized entirely from the child's point of view, with no particular regard for the sacred precincts of the other sciences. Our first major problem is to decide upon the aims of general science.

DETERMINING AIMS FROM ACTIVITIES.

Like Spencer's oft quoted query "What knowledge is of most worth?", possibly we should ask: What activities will boys and girls most likely engage in, and endeavor to find in the answer what this *general* science should be and what we should seek to accomplish through it. We may find that boys and girls are quite as much in need of training in methods of studying science as they are in need of scientific information, for control over a method by which one can learn is often more important than knowledge itself. An analysis of the activities which boys and girls are most likely to carry on will probably throw considerable light on the question of the ends to be sought through the teaching of general science. Certain general activities will be carried on by nearly every one and others will be engaged in by only a few.

It is primarily the function of the school to prepare boys and girls for carrying on such activities in an efficient manner and to lead them toward higher activities. As Professor Briggs has expressed it:

"The general purposes of the school are conceived to be two: first and fundamental, *to teach pupils to do better the desirable activities that they will perform anyway;* and second, *to reveal higher types of activities and to make these both desired and to an extent possible.* Approval of the first purpose necessitates the making for each individual pupil or group of pupils of an

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inventory of desirable and inevitable activities; from this list selection must from time to time be made on the basis of relative importance. The second purpose, which is to insure growth beyond what instincts and education outside the school may furnish, demands not only that higher activities shall be revealed but that they shall be made desirable and, so far as time permits, reasonably possible."

To make a complete inventory of activities would require a great deal of labor and much patience. Possibly it will serve our purposes for the present, and until such curriculum investigators as Professor Bobbitt and Dr. Charters, or others, can provide us with a complete inventory, to recognize certain general activities for which we should prepare students.

The Individual as a Consumer. First among these activities is that of a consumer of the fruits of science. Most individuals will have come into contact with the field of science as consumers rather than as producers. Our purpose will therefore be to develop intelligent consumers of the offerings of science. Dr. Bobbitt has pointed out that we not only live in the midst of a maze of mechanical appliances and innumerable chemical creations, but in a world in which health must be directed by science and in communities in which high standards of performance on the part of those who are responsible for such matters as our supply of pure milk, our drinking water, our street lighting and various other services depend upon an enlightened citizenry sufficiently well trained in fundamental principles that undesirable conditions and inefficient service will not be tolerated. Science offers a splendid opportunity for inculcating proper ideals of service in matters affecting the health and welfare of the people.

Seeking a Vocation. A second activity engaged in by boys and girls is that of searching for a suitable life vocation. In times long past a boy's future occupation could be predicted with a rather high degree of certainty. Life was simple. Occupations were few and unspecialized. Boys and girls commonly followed in the footsteps of their parents. Training was secured "on the job." Rarely does a boy today follow the occupation of his father. Out of all the maze of callings, some demanding much education and others little, boys and girls are expected with very little, if any, assistance or guidance, to choose wisely. Is it not the business of the school to assist its pupils in exploring some of the many possibilities that lie before them? Is it not

the function of all subjects to give glimpses into the possibilities that lie beyond, to awaken interests and arouse curiosities as to the possible opportunities which the field offers to the student? Does it not follow that one purpose of a course in general science should be to open up and to explore the field of science and its applications for the purpose of awakening interests in the subject and discovering possibilities for vocational choice? Certainly the teachers of general science have a better opportunity to give to boys and girls a general view of science as a possible field for further study than has any other group of teachers.

Leisure Activities. There is a third group of activities in which we are certain individuals will engage. I refer to leisure activities. The average person probably spends approximately 45% of his waking hours in doing something other than working at his vocation. If we include Sundays, holidays and vacation periods in addition to daily leisure periods this estimate does not seem unduly large. Surely we cannot close our eyes to the importance of training the individual to spend this large portion of his time in wholesome and profitable ways. Progressive educators everywhere are beginning to recognize the need of developing in boys and girls the capacity for right use of leisure quite as much as anything else. One of the tasks of the school is to develop lifelong interests in the various fields to which pupils are introduced in their school days. The best taught subject makes the pupil a lifelong student of that field. If the subject is well taught the pupil does not leave it with a feeling of *ennui* as he steps from the classroom. He does not feel that he has acquired all that he needs to know of the subject, but rather that he has had a very appetizing taste of it and wishes to find out more and more about it as time goes on. Now there is perhaps no field that offers greater opportunities for the enjoyment of leisure and the development of avocational interests that will tend to make happier and more efficient citizens than does science. Should it not therefore be the aim of general science teaching to develop the ability and inclination to profit by the teachings of science and to continue a lifelong interest in the subject?

Study Activities. A fourth type of activity in which everyone engages in school and in later life is that of study. This study may or may not be entirely from books. The methods of study employed in science are fundamentally the methods of systematic

study anywhere. Training in the elements of scientific method are important to everyone whether he has any intention of becoming a scientist or not. The scientist faced by an unsolved problem proceeds by making a large number of observations. He endeavors to find out which factors apply and which ones do not. He must judge as to their relative values. Finally he organizes his results and arrives at a tentative solution. This hypothesis is then subjected to further testing for verification. The methods of the scientist are essentially those of the well trained student in any line. It is the method which a well trained teacher uses in teaching her class to study a subject. Every individual is confronted by unsolved problems in daily life. Often the individual's success and well being depend upon his skill in applying proper methods and arriving at a correct solution of such problems.

He must collect his data; he must know how to evaluate them. He must decide which are pertinent, and which are not, which will lead him to true conclusions and which will lead him into false ways. Finally he must organize his results and decide upon a course of action. In such days of false allurements, misrepresentations and unkept promises as these a citizen needs to possess his own technique for testing the merits of propositions placed before him. Since the methods of approach used by the scientist and by the average citizen are in so many respect similar we may very well consider it a part of our task in teaching science to apply scientific methods of study wherever possible. Few subjects offer better possibilities for training children in good study methods than does science.

Appreciating the Work of Others. Another point for our consideration is this: To what extent should the individual be trained to appreciate properly the contributions of his fellow men to his own well being? We are constantly evaluating the work of others. We place either a true or a false value upon it. Much of our discontent and maladjustment arises out of an improper regard for the contribution of the other fellow. It is coming to be generally accepted that the more the individual is capable of appreciating the contributions of his fellow men to his own being and those he loves the better citizen he is. Since science again has contributed so largely to human welfare, should it not be a further, even though minor, aim of general science to develop, in so far as the capacity of boys and girls of beginning high school age permits, an interest in and appreciation for the achievements of science and scientific men?

If we may agree upon five points, (1) that the average individual will have occasion to use science chiefly as a consumer, (2) that science offers many possibilities for the necessary exploration of the interests and aptitudes of boys and girls, and for pointing out to them possible vocational opportunities, (3) that science offers a splendid field for training in the profitable use of leisure, (4) that methods of scientific study are needed in school and in life outside, and (5) that the contributions to human welfare made by science make it particularly suitable as a subject through which the individual may be taught to appreciate and respect the achievements of his fellow-men, may we not say that these aims should dominate the course in general science?

General Science Needed by All. If science is particularly useful in preparing men and women to live more efficiently in the home, in making them happier and better citizens, is it not desirable that all men and women should have some acquaintance with the field of science, and that all should possess some ability and inclination to apply the elementary principles of science and scientific methods to every-day life problems? At present only one child out of three in the ninth grade remains to complete the high school course. Many do not even reach the ninth grade. For this reason many men and women of the future will have no experience with the sciences except what little is provided through nature study, hygiene, and civics in the grades and what they can obtain from a study of general science, or the science of daily living, in the high school. For most persons general science is the most important of all science courses and for that reason it should constitute the core of science instruction in the schools. It must be a course organized with these aims clearly in the foreground without regard for the logic of the sciences which may follow.

Realizing Our Aims.

Our second major problem is to determine how our aims may be realized. Clearly there are two general means by which we may endeavor to realize our aims: (1) through well selected materials and (2) through good organization and suitable methods of teaching.

Criteria for the Selection of Subject Matter. There is practically no limit to the amount of material which might be used to fill a course in general science. The problem is wholly a matter of selection. We must determine the relative value of

material *for our purposes.* Subject matter of very great value in other courses may have relatively little value in a course in general science. The value attached to any material considered must be determined primarily upon the basis of its contribution to the aims of the course. For example, since we are aiming at the training of all we must choose such material as it is reasonably certain most persons will have occasion to utilize in their capacity as consumers and as citizens and which will not be supplied to them through some other agency. To quote a pertinent statement from the late Professor Inglis, "The inclusion and organization of subject matter should be determined by the importance of the various facts, principles and processes of the several sciences to the average individual in the ordinary activities engaged in by all." Commonness and frequency of use is therefore our first criterion of selection.

It is a fundamental principle of curriculum-making that a subject should be worth while to the extent taken, no matter if it be taken for but one semester or less. So long as a subject is thought of merely as a preparation for later study of more advanced phases of the subject its value is only contingent, as Professor Inglis pointed out several years ago, and unless the pupil remains in school to profit by the more advanced course, a large amount of energy will have been wasted. Since the stay of pupils in school is so highly uncertain, does it not follow therefore that general science must be valuable to the extent that the course is pursued, even though the pupil may never take any additional courses in science? Direct or independent rather than contingent value is therefore an additional criterion in the choice of subject matter for the general science course.

Closely related is the criterion of immediate value. It is far easier on the whole to interest children in material which appeals to them as something *immediately* worth while and possible of use in their own lives. Delayed applications appeal far less. Immediate use is thus an additional criterion of value.

A fourth criterion for determining when to admit subject matter to the course must be found in the abilities and interests of the pupils themselves. Since the abilities and interests of classes and of individuals differ very widely, considerable latitude should be allowed to teachers and pupils in the choice of subject matter to be taught. Naturally much of the material taken up in any well taught class will represent an outgrowth

of the questions and problems proposed by the pupils themselves. Every teacher of science would probably do well to encourage the pupils to bring in all of the live problems in science which they encounter anywhere.

The aims previously set forth demand also that the material placed in the general science course meet these additional criteria; that it be valuable for purposes of exploring the field of science, for training in methods of scientific study, for training in the use of leisure and for training the child to appreciate the achievements of science.

Organization of Subject Matter and Methods. Interests and methods by which pupils of early high school age learn should be a guiding factor in the organization of the subject matter. As Professor Snedden has expressed it, the classification of subject matter in general science must be based on such considerations as the native and acquired interests of the learner, the accessibility and appeal of the phenomena and applications to the student, and their local and contemporary significance. If learning is to be facilitated, the subject must be presented in the form of interesting experience to which the learner is attracted by his native instincts of curiosity and desire to manipulate without regard to the particular compartment of science to which the subject matter belongs. Subject matter must be organized from the child's viewpoint, i. e., psychologically rather than from the logical point of view of the scientist. The pupil, it must be remembered, knows none of the sciences by their usual names. He is interested in having questions answered that come within his experience, regardless of any cross cuts they may make over the territorial boundaries of the various sciences.

The Problem Method a Natural Approach. The most natural approach for the student is through some problem or challenge to his thinking. He is interested to find out how a certain device operates, what makes it go and how to make one like it. He wants to know, for example, how to construct a radio receiving set, what causes an eclipse, or why bread sometimes becomes moldy? These and many other questions of a similar nature are perplexing problems to him which arouse his interest and curiosity. He becomes anxious to find the answer to a number of questions which only a study of science can answer.

For a number of reasons the problem furnishes one of the best methods of approach to the study of science. First of all it

focuses attention on a live interest center which motivates not only the discussion but the reading and other investigation. Second, it provides a basis of organization around which the reading and discussion center. Third, it gives the student an opportunity to weigh values, to decide as to the relative importance of the various elements and to decide what constitutes good evidence and what does not. Fourth, it affords the pupil an immediate opportunity to use the knowledge he has already acquired, which is one of the best guarantees for learning the facts that are of real importance. Fifth, the method of the problem is essentially that of the scientist and is the method we wish him to acquire in order that he may become a more nearly independent student. If we grant that the material should be organized around live problems of interest to the children, our course in general science will be organized primarily in terms of the *applications of science* rather than as so much of each of the separate sciences. The psychological interest of the child rather than the logic of science will be the determining factor.

Training in the Reading of Science. If we are to realize our aims in general science teaching it will be necessary to see to it that our pupils are trained in the reading of science. The teacher who has not attempted to measure the abilities of her pupils in various types of reading skill demanded in the study of science will probably be amazed at the deplorable lack of reading ability exhibited. Can the pupils really understand the thought? Do they understand the common vocabulary of science which we take for granted they do? Can they look up and find exact pieces of information when occasion demands, or are they likely to bring in something very different? Can they follow directions? Can they organize the material they read into outline form? Are they able to trace cause and effect relationships? Are they in the habit of challenging statements encountered in their reading? Can they utilize the available references to prove or disprove such statements? These are all reading abilities demanded by one who would be a student in any field and relatively little progress will be made without them.

Wide Reading for Experience. The attainment of our aims will be further promoted by the use of methods that contribute to wide observation and diversified reading. As Dr. Bobbitt puts it, "The basis of all science learning must be abundant experience with concrete realities, working with them, using them, controlling them, play that involves them, observations

and abundant and revealing reading." The task of the teacher is to enrich the experiences of the child so that he may have a large reserve upon which to draw for his applications. It is a commonly accepted principle of learning that facts and principles are more readily learned when presented in the form of a wider experience which carries with it emotional warmth and imagination than when presented as mere facts. Moreover, if the child is to develop the habit of wide reading in science when he leaves school, steps must be taken to build such habits while he is in school.

Going Outside of the Textbook. It is extremely unlikely that the demands of a course in general science can be met by staying within the confines of a single textbook, much as a textbook may tend to relieve the teacher from the burdens of collecting and organizing supplementary material. In all probability the textbook can never be more than a reference. Realization of the aims of the course in general science will demand not only a great deal of reading for experience but carefully planned excursions and field trips of various kinds. Science must be seen and studied in its actual setting if it is to serve as exploratory material for developing the interests and discovering the aptitudes of boys and girls. Individual laboratory work of the type employed in the more advanced sciences probably has very little place in general science. The outgrowth of the pupil's reading and observation should stimulate him into a desire to investigate and experiment of his own accord. Probably no boy ever studies science so energetically or masters it so well as the boy who becomes so interested in some phase of science that he sets up his own laboratory at home and works out his own projects.

CONCLUSIONS.

Answering our original query "How to accomplish our aims in general science," we may say that:

1. We must first decide what the aims of general science should be. These aims are to be found very largely in an analysis of the activities in which most individuals engage. They are primarily (a) those of a consumer of the fruits of science, (b) those connected with finding a life vocation, (c) those associated with leisure, (d) those connected with the solution of problems met by the student in life and (e) those connected with a proper evaluation of the achievements of one's fellowmen through science.

2. Not only is it the function of the school to prepare boys and girls for carrying on such activities in an efficient manner but

to lead them to aspire toward higher activities revealed through proper teaching.

3. Since many do not complete the high school course general science becomes the most important science for boys and girls and should constitute the core of the science curriculum in the high school, without any particular regard for the sciences that may follow.

4. The material included in the course of study should be chosen in accordance with its relative value. Not only should it contribute to the aims of the course but it should have direct and immediate value for the child and be suited to his interests and abilities.

5. To facilitate learning the material should be organized primarily from the child's point of view, i. e., psychologically, rather than from the point of view of the scientist. The most natural approach for the student is through the form of challenging problems which stimulate thinking and provide centers of interest around which the pupil may gather his data and apply the information he has acquired. To meet our needs the course should be organized primarily in terms of the *applications of science* rather than as bits of separate sciences.

6. If we are to realize our aims in general science it will be necessary to give some little thought and attention to the training of pupils in the reading of science. Without a proper development of the essential reading abilities little progress is to be expected.

7. The attainment of our aims will be promoted by methods that contribute to wide observation and diversified reading in the field of science, which will enrich the experiences of the pupil, and which will develop the habit of continued reading of science after he leaves school.

8. The demands of a course in general science probably cannot be supplied by a single textbook. The class text must be augmented by much general reading and observation of science in its natural setting, the outgrowth of which should be a desire on the part of the student to carry on his own investigations.

In conclusion it may be said that the teachers of general science have an important mission to fulfill and an opportunity such as teachers of few, if any, other subjects have. The way is still largely uncharted, but no one who has followed the development of general science for the past ten years can say that progress is not being made.

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THE QUANTUM THEORY.

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There are two outstanding features in modern physics, the relativity theory and the quantum theory. The former has been reduced to a perfectly logical conception of time and space, so that it now stands as a metaphysical doctrine having certain points of contact with experimental physics. We may regard it as complete and fully accepted, except as doubt is thrown on the original experiments that gave rise to it.

On the other hand, the quantum theory involves certain very puzzling inconsistencies, and must therefore be looked upon, not as a triumphant achievement of scientific research, but rather as a very intriguing puzzle. Twenty-five years ago, we were naively unconscious of the difficulties which it involves, and were therefore far more complacent than we now dare to be. The purpose of this paper is to explain, as simply as possible, what the quantum theory is, and to point out the chief dilemma to which it leads,—not, however, to suggest a solution.

The theory is concerned with interchanges of energy, a quantity the name of which is familiar to every modern reader. However, since the word energy is used by the man in the street as synonymous with force, power, vigor, pep, and several other words, some of which have places in the scientific vocabulary with different meanings, it becomes necessary to start by explaining the precise meaning of energy in physics and chemistry.

The energy of a body is an attribute, or possession, of the body, which is expressible in exact numerical terms, like its length or weight. A body's weight is so many pounds or tons, its length so many millimeters, feet or miles, and its energy so many ergs, calories, foot-pounds, or British thermal units.

The simplest form of energy, called *kinetic* energy, is energy a body has purely because it is in motion. Numerically, it is equal to the square of the body's velocity multiplied by half its mass. If we roll a little ball, of mass 8 grams, across the floor

with a speed of 50 centimeters per second, its kinetic energy will be 10,000 ergs. (The energy due to the rotation of the ball has been neglected in this calculation. If taken into account, it would increase the kinetic energy about 40%). You will notice that the erg must be a very tiny unit, but that fact is unimportant. It is more important to see that the conception of kinetic energy is at least clear and positive, although you may think the physicist's way of calculating its value is rather arbitrary.

If the ball be held in the hand and dropped from any height to the floor, it has at the start no kinetic energy, but it gains in kinetic energy as it falls. The greater the height from which it is dropped, the greater its kinetic energy on reaching the floor. You see that when it is held at a certain height, although it has no kinetic energy actually, yet it has some *potentially*, for in yielding this position it gains a definite amount. Therefore we ascribe to it, in the raised position, *potential* energy, in amount equal to the *kinetic* energy it gains by giving up the favored position. For this particular case, the potential energy of the ball depends upon the force of gravity, but we can equally well have cases where it depends upon elasticity, or upon electric or magnetic forces. The compressed spring in a child's spring-gun has potential energy, in amount measured by the kinetic energy it can impart to a bullet.

Coming back to the ball, we know that if it hits the floor it will bounce, but not so high as its original position. We say that some of its energy is lost, because of air-resistance and imperfect elasticity. In all such cases where mechanical energy is lost, a certain amount of heat makes its appearance, and a number of very careful experiments have shown that there is an exact constant ratio between the amount of lost mechanical energy and the quantity of heat produced. One calorie is produced for every 41,870,000 ergs of lost energy. From this we infer that heat is a form of energy, the calorie being merely another unit of energy, a much larger unit than the erg, just as a century is a larger time-unit than the second.

There are still other forms of energy, such as chemical energy. For instance, when hydrogen and oxygen gas combine to form water vapor, a large amount of heat is produced. Therefore we say that these gases when uncombined possess more energy, by a definite amount, than when combined into water vapor.

An electric current possesses energy, in amount measured either by the heat it will produce, or by the kinetic or potential energy that it can impart to objects by means of motors. For reasons of convenience, engineers express the energy of electrical circuits neither in ergs nor in calories, but in *kilowatt-hours.* (One KWH $=36\text{x}10^{12}$ ergs $=859804$ calories). When one pays his monthly bill to the local power plant, he is paying for energy, delivered to him by electrical means, but used by him either in the form of heat—as in lamps, curling-irons, flat-irons, percolators, etc., —or as mechanical energy—as in vacuum-cleaners, washing-machines, and other motor-driven devices.

Energy can be carried from place to place by waves. The engines of a ship must furnish energy, not only to push the prow through the water, but also to form continuously anew the large bow and stern waves which carry their energy far out from the path of the ship.

A musical instrument also sends out waves, though of a different kind, which swell out as expanding spheres from the instrument as a center. Each wave carries a certain quota of energy with it, and the small part of the wave that reaches the ear-drum transfers its energy to the drum and the mechanism of the middle and inner ear, and by some process which may be forever beyond our comprehension causes the sensation of hearing.

Light also is a form of energy, for if it is absorbed by a blackened object that object becomes warmed. The standard method of measuring the energy in a beam of light is by the heat it produces when absorbed.

We have very strong reasons, based on interference experiments, polarization, reflection, refraction, etc., for believing that light, like sound, is carried through space by waves. This theory has been accepted for one hundred years or more, but before that it was believed by many, chiefly on Sir Isaac Newton's authority, that light consists of very minute corpuscles shot out from the body with enormous and invariable speed. Now it is a very remarkable fact that in recent years certain physicists have shown a disposition to revive this old corpuscular theory of light, in an altered form, and the facts that have led them to such a radical step are precisely those facts that gave rise to the quantum theory.

In approaching the quantum theory from this angle, we are going in by the back door, so to speak, but I believe this is the best way to present the kernel of our difficulties.

One of the differences between the wave theory and the corpuscular theory is that the latter is an *atomic* theory, necessarily, while the former is not. If a beam of light is a stream of corpuscles, each corpuscle carries a definite *atom* of energy with it. A luminous body can emit, an illuminated body can receive, any integral number of such units, but not a fractional number. The diminishing intensity of a beam of light at greater distances from the source is due to the corpuscles becoming wider distributed at greater distances, but each corpuscle will retain its atom of energy intact until the whole corpuscle is absorbed.

On the other hand, if light consists of waves, the energy is distributed continuously over expanding spherical surfaces, and the brightness diminishes with distance simply because the energy is thinned out by being spread over an immense area.

Now this is an age of atomic theories as contrasted with continuity theories. Someone once remarked in the Latin tongue that Nature does nothing by jumps, but it now begins to look as if the lady has St. Vitus' dance. The original atomic theory of the chemists has been supplemented by the electron theory, still more extremely atomic. The old theory of biological evolution by continuous variations has given way to the theory of discontinuous mutations, and eugenists tell us that inheritance is a mosaic of *unit characters*.

As for energy, so far as we know a body's velocity may have any value we like, and therefore its kinetic energy may have any value, not restricted to multiples of any particular unit. The first proposal that energy might in any sense behave as if atomic came about 1900 from Max Planck. Planck is a very scholarly German, who took as his principal life-work a certain abstruse physical problem which I shall not try to explain. It is a problem that had already balked a number of mathematical physicists, and Planck finally convinced himself that it is incapable of solution except by making a very radical hypothesis, viz., that either the act of emission of light, or the act of absorption of light, or both, occur by chunks, to use a rather crude expression. Here we have the start of the quantum theory. A *quantum* is a sort of atom of energy, the smallest amount that can be emitted by a radiating material atom, or absorbed by a receiving atom. However, the quanta are not all of the same size, but depend upon the color, or wavelength, of the emitted or absorbed light. For the deepest red light, the quantum is about 2.5×10^{-13} ergs, for the farthest violet about twice as much.

It is doubtful whether Planck's quantum proposal would have been quite seriously considered, but that within a few years it was found that a number of other unexplained phenomena give support to it. I shall go into detail with only one of these phenomena, the *photoelectric effect*. About forty years ago, Hertz, the father of radio, found that a metal plate illuminated by light, preferably ultraviolet, will acquire a positive electric charge. Later it was shown that the immediate effect of the light is to cause the metal to throw off electrons (negative charges) and the positive charge remaining on the plate is simply the result of the loss of these electrons. A method was devised for measuring the velocity of the ejected electrons, and then a surprising discovery was made. This velocity does not depend at all upon the brightness of the light, but only upon the wavelength. Let us picture the experimental arrangement. A zinc plate is set up, facing some source of light, say a mercury arc so screened that the light of only a certain wavelength can reach the zinc. Whether the lamp be 6 inches from the plate or 40 feet, the ejected electrons have the same velocity, though of course more are ejected per second when the illumination is stronger.

Einstein, the relativity man, pointed out that Planck's quantum hypothesis fits in very nicely here. If the energy of the electron ejected from a zinc atom comes from the energy of the light which the atom absorbs, then the magnitude of the quantum of energy must determine the energy of the electron, and the magnitude of the quantum, as we know, depends upon the wavelength of the light. The agreement is actually quantitive, for if we correct the energy of the ejected electron for a certain loss it suffers in getting free from the metal, we get just the amount of energy that Planck's theory ascribes to the quantum.

Now all this would be quite simple on the corpuscular theory. Each corpuscle would carry a certain amount of energy, a quantum. If the source of light were near the zinc plate, many corpuscles would strike the latter, if far away, few,—but each hit would have the same effect, the transfer of the energy of a corpuscle (a quantum) to an electron, which is ejected. On the other hand, an explanation seems almost unthinkable if we adhere to the wave theory of light. Suppose, for example, that a quantum of energy is emitted from the source in the form of a train of waves. If the train is emitted impartially in all directions from the source, this quantum would, at the distance of 40 feet, be spread over an area of nearly 50,000 square-feet. How

could a single zinc-atom absorb it? Even if the emission of a quantum in waves were considerably localized, unless it were localized to the extent that it followed almost thread-like paths, it is hard to understand how it could be absorbed as a unit.

Here we have the dilemma that faces the physicist today. On the one hand, the facts of interference, polarization, reflection, refraction, the constancy of the velocity of light in a given medium, all seem to compel us to believe in the wave theory. On the other, the facts giving rise to the quantum theory seem entirely inconsistent with waves. And yet, by using both the wave theory and the quantum theory together as if they were perfectly consistent, most remarkable success has been achieved in explaining the phenomena of X-rays, optical spectra, and other things.

Some rather vague suggestions have been made toward reconciling these apparently contradictory facts. One, which seems to me of interest, involves an extension of the relativity theory. This has already acquainted us with the notion of curved space, and Professor Jeans has made the suggestion that besides being curved, space has a sort of scaly structure, which might in some way account for the quantum relations.

THE MAGNETIC VARIOMETER.

By A. L. Fitch,

Professor of Physics, University of Maine

The magnetic variometer is an instrument for comparing the horizontal component of the earth's magnetic field at any place with that at any other place or for comparing this quantity for the same place from time to time. It consists of a long compass needle which turns on a jeweled bearing over a graduated scale, supported coaxially with a strong bar magnet which is also provided with a graduated scale. The magnet may be turned completely around its support and be raised or lowered at will. The field of the bar magnet is superposed on that of the earth and the position taken by the compass needle is determined by the resultant of these two fields. It is evident that the closer the bar magnet is to the compass the greater will its effect be. For greatest sensitivity, the magnet must not be too close.

One method of using the instrument is as follows. The instrument is leveled and set so that the zero of the compass

scale is approximately in the magnetic meridian with the 180° mark. The magnet is then raised with its north seeking pole north until the compass needle reverses, the north seeking pole points south. In this position the magnet scale should read zero and the compass scale should also read zero although it is not necessary that they do so. This is illustrated in Fig. 1. The magnet is then rotated on its vertical axis dragging the compass needle with it until the compass reads exactly 90°. The position of the magnet is then read. Call this angle θ_1. This

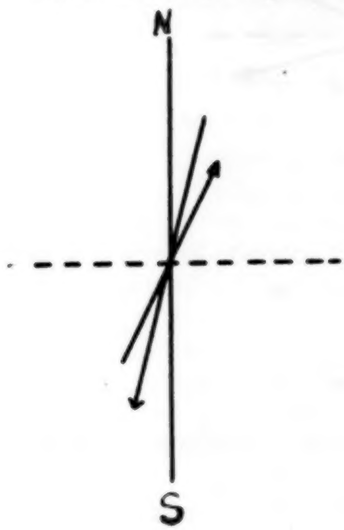

Fig 1.

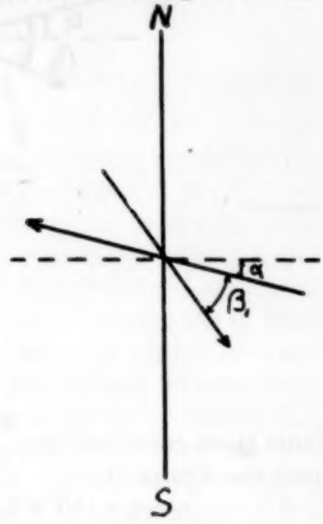

Fig 2.

position is illustrated in Fig. 2. In this position a component of the earth's horizontal field counterbalances a component of the field due to the magnet. This may be written

$$H \cos \alpha = F \sin \beta_1$$

where H is the horizontal component of the earth's field, α is the angle between the compass needle and a line drawn due east and west, normal to the magnetic meridian, F is the field at the center of the compass due to the bar magnet, and β_1 is the angle between the axis of the magnet and that of the compass needle. The bar magnet is then rotated in the opposite sense until the compass needle is reversed i. e. reads 270°. This position is illustrated in Fig. 3. Call the angle read on the magnet's scale θ_2. In this position

$$H \cos \alpha = F \sin \beta_2$$

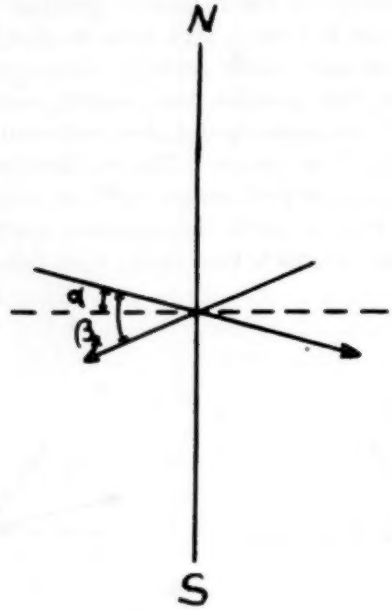

Fig 3

From these equations, it is evident that β_1 equals β_2. It is seen from the figures that

$$\theta_1 + \theta_2 = 180^\circ + \beta_1 + \beta_2 = 180^\circ + 2\beta$$

or

$$\beta = \frac{\theta_1 + \theta_2}{2} + 90^\circ$$

and

$$H \cos \alpha = F \sin\left(\frac{\theta_1 + \theta_2}{2} + 90^\circ\right) = F \cos \frac{(\theta_1 + \theta_2)}{2}$$

At some other place the experiment when repeated with the magnet at the same distance below the compass needle will give

$$H' \cos = F \cos\frac{(\theta_1' + \theta_2')}{2}$$

When these two equations are divided member by member

$$\frac{H}{H'} = \frac{\cos \dfrac{(\theta_1 + \theta_2)}{2}}{\cos \dfrac{(\theta_1' + \theta_2')}{2}}$$

The ratio of the horizontal field intensity of the earth at any place to that at any other place is seen to be the ratio of the cosines of two angles. It is not necessary that the scales read zero at the outset or that the compass needle lie exactly in the magnetic meridian.

A PRELIMINARY REPORT ON THE PROGRESS AND ENCOURAGEMENT OF SCIENCE INSTRUCTION IN AMERICAN COLLEGES AND UNIVERSITIES, 1912-22.[1]

By N. M. Grier.

I. Introductory and Resumé of Related Literature.

A. Science in the High Schools 1908-23.

Previously published studies dealing with the enrollment in science instruction appear to be mostly limited to the field of the secondary school. It may be that comments on the situation there apply with equal pertinence to the situation in colleges and universities, as it is possible that similar factors, economic, social, etc., influence the progress of science instruction in both secondary and higher education. In the high schools, for example, subjects which will later help the students to earn their living, such as commercial studies, will naturally receive the greatest administrative support. The same idea may influence the progress at times of the collegiate and university sciences, and perhaps may become more evident if the enrollments of the higher institutions continue to increase as they have during the past few years. A corollary, perhaps, is, that strong or weak science departments in high schools will create temporary or lasting interests in science among students, which may carry over into the higher institutions and thus affect their enrollment in science subjects. For the preceding reasons, the following summary of the more comprehensive papers dealing with the enrollment in science in the high schools is given, as it will be the effort of the writer to develop such data as he has from the higher institutions along similar lines. Fisher[2] pointed out that all of

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[1]Paper presented before Sect. 2 (Education) A. A. A. S. at Washington, D. C., December, 1924. I am indebted to Professor Stewart Rice of the Univ. of Penn. and Mr. C. D. Dieter, Washington and Jefferson College for aid extended in the preparation of this article. Contribution from the Committee on the Place of the Sciences in Education, American Association for the Advancement of Science and the Department of Evolution, Dartmouth College.

[2]Fisher, W. J. Is Science Really Unpopular in High Schools? Science N. S. Vol. XXXV: 94-98.

the natural sciences taught in the high school, (geology, astronomy, chemistry, physics, physical geography and physiology) had dropped in enrollment, some of them enormously. Possible causes for the diminution in the popularity of the subjects he found to lie in the shifting of these studies into the later years of the course where they became less available to students. He concluded from other observations that American girls and boys liked the sciences, both exact and natural, better than they liked the languages provided they only had as good a chance to get at them, and the way to save the situation for science was to give them a chance early in the course. Later,[3] he published a chart showing the decline in scientific studies as compared with the humanistic from 1900-06. This decline he also found continued in 1910, while the Report of the U. S. Commissioner of Education for 1913, Chapter 5, states, "we note therefore the phenomena of a decline in the ratio of students who elect science."

Downing[4] admitted a decline in the percentage of students electing physics, chemistry, physiography and physiology but felt it doubtful that there was a decline in the sciences and an increase in the humanities. He believed that any apparent decrease could be explained by the shift of students with scientific interests to other subjects like botany, agriculture, domestic science, or that it was conceivable that while the enrollment had declined, the length of time devoted to the sciences by all the students remained fairly constant. He observed that the data from which Fisher made his study could be combined as to indicate that the enrollment in the sciences had increased much more rapidly than the enrollment in the classics and more rapidly than anything in the tabulation except English. Downing also concluded that the data showed that the classical studies had grown in disfavor more rapidly than the scientific among high school graduates intending to go to college; that the increase throughout the country in the enrollment of Latin and the decrease in physics, chemistry, physiology, etc., might be due to changes in restricted regions which were not standing in the position of educational leadership. He adds, however, that the data for the sciences is incomplete, and this apparently erratic rise of science instruction may be due to the continued introduction of science data. Atthat time (1905) he pointed out that botany, zoology, agriculture, and domestic science were apparently only

[3]Fisher, W. J. The Drift in Secondary Education. Science N. S. Vol. XXXVI:587-90.
[4]Downing, E. R. The Scientific Trend in Secondary Schools. Science N. S. Vol. XLI: 232-235.

of sufficient importance in recent years in the high school curriculum to have their enrollment reported. Yet the table gives the impression that the decline in physics, chemistry, etc., is due to the shift of students to these newer subjects. Finally, he felt the Fisher data did not show the trend of secondary education.

In the second of his papers[5], Downing noted that in the five year period (1910-14), as covered by the report of the U. S. Commissioner of Education for 1916, there had occurred a drop of 44 per cent in the enrollment of botany stated in terms of the total enrollment and of 51.3% in zoology. The decline in botany was found to be from 16.34% to 7.19% and in zoology from 7.88% to 4.04%. Physics was found to be nearly holding its own, changing from 14.79% to 14.28% while chemistry had made a slight gain, from 7.13% to 7.63%. Other old line sciences such as physiology, physiography also dropped off quite heavily. The gain in the newer high school sciences such as agriculture, domestic science, was sufficient to counterbalance the loss in the old. The percentage of enrollment in agriculture had increased from 4.55% to 6.9%, in domestic science from 4.4% to 12.6%. The total percentage enrolled in science in the high school in 1909-10 was 91.99%; in 1914-15, 86.16%, a drop of 5.83%. Downing found the largest decline in botany and zoology had been in the north Atlantic States where the percentage of enrollment had dropped in the five year period from 16.28% to 6.46% in the former subject and in the latter from 9.64% to 3.18%. Simultaneously, however, the enrollment in biology had risen from 2.35% to 14.38%. The percentage of enrollment in botany had changed from 17.72% to 12.79% in the North Central States, and in zoology from 5.57% to 3.49%, but at the same time the enrollment in biology had risen from 0.13% to 1.64% and in agriculture from 4.97% to 9.78%. Downing remarks in conclusion that botany and zoology were apparently giving way to related subjects that either appeal to school authorities as more effective educationally or to the public as being more closely allied to everyday affairs. He felt, however, that the decline in the percentage of students in the old line subjects was largely due to the introduction of many new subjects like manual training, domestic science, biology, agriculture, drawing, and that the science group was holding its own reasonably well, this being especially true of physics and chemistry.

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[5]Downing, E. R. Enrollment in Science in the High Schools Science N. S., Vol. XLVI: 351-352.

It was also his opinion that the data indicated that botany and zoology would be eliminated from the high school curriculum, asserting, however, that they may reappear under a new caption. It is interesting to note also that Downing found modern languages to be the only one of the traditional subjects that showed an increase, decreases being shown in the classics, mathematics, history and English.

Hunter[6] in 1908 and 1924 studied the sequence of science in the high school by means of questionnaires sent to five hundred leading public high schools in various parts of the United States. In 1908, he found that 276 schools reported nine courses in general science, 166 courses in physiography, 641 in biological subjects (of which 73 were in biology, 193 in human physiology, 225 in botany and 150 in zoology), 253 in chemistry, 267 in physics, and 35 scattering courses including astronomy, geology and sanitation. In 1923, 368 four year schools reported 252 courses (of which 311 were in biology, 165 in human physiology, 123 in botany and 73 in zoology), 413 in chemistry, 426 in physics and 19 scattering courses.

Comparison of the replies from the two questionnaires shows that there has been gradual but healthy increase in the total number of science courses given in the four year secondary school. Other tables he includes indicated that the percentage of courses in general science, biology, chemistry and physics has increased in the four year secondary school, while the percentage of courses in botany, zoology, physiography, and physiology and other courses in science has decreased. He accounts for the smaller percentage of courses in these latter subjects by the fact that much of the material in them has been absorbed by the courses in general science and biology.

Hunter includes in his later paper a section of a report[7] of the Bureau of Education which appeared during the school year 1922-23, which shows that in cities having a population of more than 100,000, 16.32% of the high school pupils are enrolled in physiology and hygiene courses, 14.84% in general science courses, and 13.08% in biological courses. When it is noted that in these same schools traditional Latin enrolls 23.33% of the pupils and French and Spanish each a little over 21% of the

[6]Hunter, G. W. The Methods, Content and Purpose of Biologic Science in the Secondary Schools of the United States. SCHOOL SCIENCE AND MATHEMATICS X, 1910, p. 1-10; 103-11.

Hunter, G. W. The Place of Science in the Secondary School, I and II.
[7]School Review, XXXI, 564. 1925.

pupils, he remarks that it is seen that a fair proportion of the pupils are becoming acquainted with the science subjects. He refers to other articles also in which increases in science enrollment for specific localities are indicated.

Hunter remarks also that the most convincing report is a summary of the Pennsylvania report for 1923 on the status of the sciences in all the four year high schools of the state. This report shows that the general science is given in nine hundred and ten of the one thousand and five high schools of the state required in 76.9% of these schools in the first year, and elective in 23.1%. Biology is given in 871 schools, required in 51.5% of them and elective in 63.6%. Chemistry is given in five hundred and twenty-eight schools, required in 18.2% of them and elective in 81.8%. Additionally, his returns indicate that science is more strongly intrenched than it was fifteen years ago in that a greater number of hours are devoted to the subject in most schools.

It is observed that these results of Hunter confirm Downing's predictions concerning the passing of the old line of biological and geological sciences, but that he finds between the periods in which he sent out his questionnaires a healthy growth in the high school science courses. The results of these three investigators suggest a rhythm in the fluctuating enrollments of the high school sciences, which may represent their response to external conditions of which we know very little, but which are undoubtedly of sociological and economic significance.

B. Enrollments in the Higher Curricula.

It is possible that corresponding readjustments may be expressed by changes in the enrollment in subjects in the college curriculum. For example, mathematics has ceased to be a required subject at many colleges and such a change has most likely been accompanied by a fall in the enrollment in this subject. Again, those connected with colleges and universities realize that the subjects of instruction preferred by students follow successive fads in the course of years. The classics and sciences in recent times have yielded their first line position to English, and the more recently developed economic, political and social sciences.

The situation in Latin and Greek, both in the college and in the secondary schools, has been made the subject of study by the Advisory committee of the American Classical League.[8] The

[8]The Classical Investigation. Part One. General Report. Princeton University Press, Princeton, N. J.

enrollment in Greek in the secondary schools is reported as being low (p. 16), and showing some sign of increase, "but it is so small as to cause deep concern to all friends of classical education" (p. 18). "The decreased percentage in Latin enrollment as compared with the total enrollment in the public schools during these seven years (1914-21) was to be expected. This decreased percentage in the combined modern foreign languages is accounted for by the enormous increase in the total enrollment of those schools" (p. 12). . . "The recent rapid increase" following a sagging in Latin during the World War is encouraging (p. 250). "Many colleges report an increasing interest in the two classical languages" (p. 23). The past failure of Latin is attributed to faulty methods of teaching, content of courses, and in other cases to discouragement offered by educational authority. The status of enrollments in modern languages is understood to be the subject of study by that Association at this time.[9]

So far as the sciences of the Higher Curricula are concerned, the writer is aware of but one study having a bearing on the progress of science instruction, and this deals with agriculture[10] in part, a specialized branch of botanical science.

"The total number of students enrolled in the forty-eight Land-Grant Colleges of the United States has increased 112% during the past ten years. During the same period the number of students enrolled in agricultural courses in the same colleges decreased 3%.

"The decrease in agricultural college enrollments in recent years apparently has reflected the economic depression which agriculture has experienced. Similarly the marked increase in agricultural college enrollments during the ten years preceding our entry into the World War apparently reflected in part the increasing prosperity of agriculture during that period.

"Post-war declines in agricultural enrollments have been accentuated, according to the deans of the agricultural colleges, by the graduation of United States Veteran Bureau trainees and by the development of agricultural extension work and agricultural education in high schools.

[9]With regard to the present situation in modern languages, the following quotation from a letter of Professor Algernon Coleman of the University of Chicago, Special Investigator for the Modern Foreign Language Study, written under date of December 2, 1925, is of interest.

"We are not in a position to say definitely what the tendencies are in the enrollment in modern languages. . . My impression is that the registration in Modern Languages is relatively at a standstill, a fact which is very closely connected with the stupendous increase in secondary and college enrollment in proportion to the population, and consequently greater number of persons who are not interested in the sort of course represented by modern language study. These, however, are impressions and not facts."

[10]Cited from the summary of "One Measure of Agricultural Trends" Published by the Agricultural Bureau, Natural Sources Production Department, Chamber of Commerce of the United States, pp. 2-4.

"Agricultural colleges in the middle Atlantic and East North Central States have suffered the greatest losses in enrollments. Agricultural college enrollments in the New England, West North Central and Pacific Coast States have decreased slightly. Agricultural college enrollments in the Mountain and Southern States have increased considerably during the past ten years, but the increases have not kept pace with the decreases in the total Land-Grant College enrollments.

"In proportion to the agricultural resources—farm population, number of farms, value of farm property and value of farm products—of their respective states, the New England agricultural Colleges have the greatest number of students. The Southern States have the fewest. However, a larger proportion of the agricultural students in New England agricultural colleges are from the cities than is the case in other sections.

"Enrollments of short course students in agricultural colleges have decreased 14% during the past ten years. Although the agricultural college heads are of the opinion that extension work and high school agricultural students are taking the place of short courses in some degree, they cite the decrease in short course enrollments as a further reflection of the agricultural trend."

"In 1924 there were 3% fewer agricultural college students than in 1914 and 16% fewer than in 1916. This decrease assumes larger significance when compared with the increase of 112% in the total enrollments in Land-Grant Colleges between 1914-23. In 1916 the agricultural enrollments made up 22.5% of the total Land-Grant College enrollments; in 1923 they made up but 11.5%.

"Enrollments of college students in agricultural courses reached their peak in 1916, having increased from 2,900 to over 15,000 in ten years. Since 1916 agricultural college enrollments have followed an irregular course. They decreased slightly in 1916-17, dropped off sharply during the following two war years, in 1920 increased to almost the 1916 level, and then declined steadily through 1924. During the ten year period ending in 1916 the rapid increase in agricultural college enrollments reflected the natural growth of the agricultural colleges and the increasing prosperity in agriculture. During this period the agricultural colleges were erecting new buildings, adding to their equipment and teaching staffs, and expanding their curricula, for although most of the Land-Grant Colleges were established during the

latter half of the 19th century, many of their agricultural departments had their beginning during the early years of the twentieth century."

The object then of this paper is to consider the status of science in certain American Colleges and Universities during the years 1912-22, a period which if interrupted by the war was inaugurated by unusually favorable economic conditions, and one toward the end of which the total enrollment of the institutions concerned greatly increased and important changes in their curricula took place.

II. Method.

This study is based upon the partial and entire statistics for the science of thirty-seven institutions for the years indicated, and represents the number of colleges and universities responding to over two hundred and fifty questionnaires and their follow-ups sent out. In some cases the basic data was obtained from the annual reports of the institutions. The great majority of the institutions considered have an endowment of $1,000,000, or over. The collegiate sciences considered are those of astronomy, biology (botany, zoology, physiology), chemistry, geology (geology, mineralogy, geography), and physics. The questionnaire called for the enrollment in each division of these sciences for each semester over the period of years covered by the study. Grouped under the categories under which they will hereafter be referred, the institutions contributing data are as follows:

New England Women's Colleges (N. E. W. C.).

Simmons, Mt. Holyoke, Wellesley, Radcliffe, Connecticut College for Women.

New England Men's Colleges and Coeducational Institutions (N. E. M. C. I.).

Maine, Clark, Williams, Dartmouth, Tufts, Middlebury.

Northern Institutions (N).

Vassar, Bryn Mawr, Toronto, Lafayette, Union, Colgate, Ohio Wesleyan, Princeton, Columbia, Oberlin, Wooster.

Southern Institutions (S).

Westhampton, Goucher, Randolph-Macon, George Peabody College for Teachers, Mississippi, Sweet-Briar.

Western Institutions (W).

Carlton, James Milliken, Wisconsin, Nebraska, Arizona, Utah, University of Southern California.

Included in the statistics are data from two institutions where the senders neglected to put the names of the college in the questionnaire and which it proved impossible to trace. These were designated X1 and X2. To secure uniformity in all the institutions considered, the registration statistics for the summer schools, extension courses and the preparatory courses were omitted but those of the graduate and professional schools were included. In the case of institutions which submitted complete data of this kind for the years 1912-1922 inclusive, the basal year was made that of 1912-13, which, as already mentioned, is considered a favorable year for such a comparison from the economic standpoint.

The data secured was treated in two ways designed to bring out (1) the status of enrollment in science at each institution treated as a unit, and (2) the status of this phase of science instruction in more absolute terms. In the first case the percentage of the total enrollment for 1912-13 represented by the enrollment in a particular science for that year was calculated and then percentages were computed similarly for each of the succeeding nine years for all of the institutions concerned. The average obtained for the year 1912-13 indicated whether or not the subject had increased during that time; i. e., whether or not it had held on the average by the end of the tenth year, the relative ratio to the total enrollment it had held in 1912-13. This nine year period was viewed as a unit in this way, to avoid being misled by the fluctuations of individual years and to indicate the relative progress of the particular science at a given institution. The results of these calculations for each science are given in following parts of the paper, and indicate the number of institutions whose enrollment in a particular science showed an increase and the number which showed decrease.

In the case of those institutions which could not supply complete dâta, the basal year taken was the one for which their earliest data was reported and then the same procedure was followed as in the case of the other colleges. While it is unfortunate that uniformity could not be had here, yet in no case was the partial data for a later period than five years, which may be a fair period in which to detect a relative decrease and increase in general enrollment. Possibly the results of the procedure will indicate to a certain degree whether the conditions in a greater or less number of institutions were favorable to the teaching of

a particular science during the years mentioned. Any erroneous impressions secured may be neutralized by conclusions from the graphs accompanying the paper, which have been drawn with separate considerations of the partial and complete data.

The graphs illustrating the second method of treating the data were constructed in the following manner. The total enrollments of all the institutions submitting complete data were added together for each year from 1913 to 1922 inclusive. This sum for each year was then compared with the corresponding sum for 1912 in terms of per cents. This data forms the basis for the curve entitled "total enrollments of institutions." The data for the curves for separate subjects was obtained similarly and likewise plotted for the years considered. Thus an absolute increase or decrease in a particular subject was shown, which would give some view of the progress of the sciences quite independent of the conditions under which they might be taught at different institutions.

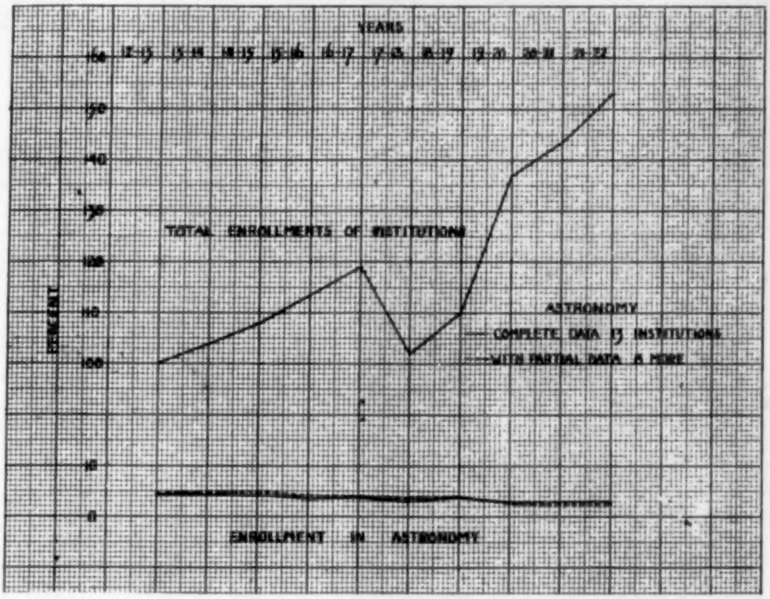
III. Results.

Here the main subjects concerned are treated in alphabetical order, their sub-divisions following them.

Astronomy.

For this subject complete information was furnished by thirteen institutions; eight others sent partial data. Seven institutions show an increase in the enrollments in the subject, ten a decrease with four exhibiting no gain. Three of the women's colleges show an increase, two a decrease, and three no change. The greatest gain in astronomy is found in the western institutions, the New England women's colleges following closely. The greatest loss is found in the Northern Institutions followed by the New England men's and coeducational colleges, southern women's institutions and unclassified institutions.

The total enrollment in the institutions concerned rose 54 per cent by 1921-22. All data available for astronomy indicates that this subject is slowly going down-hill. The enrollment is shown by the graph as 2 to 3 per cent less in 1922 than it was in 1912. A possible cause of the failure of this old-line science to attract more students may be found in the fact that much of its more interesting material is already offered in the so-called "orientation" courses of colleges, wherein student interest in this subject may become satiated. It is not probable that the mathematical nature of astronomy gravitates against its attracting large numbers of students in the present generation,



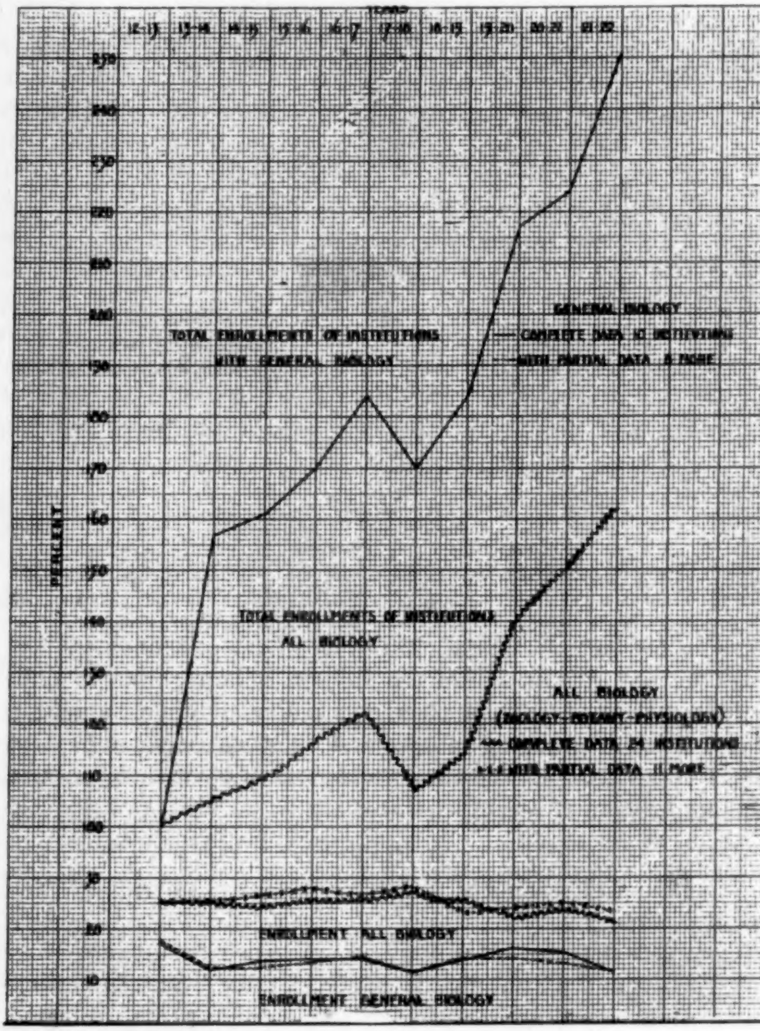
as it is not usually taught that way. Some astronomers feel that the present position of the subject is largely due to difficulties concerned with its place as a major or minor subject in any particular grouping of studies. That astronomers have at heart the welfare of their science is shown by their interest in the preparation of recent textbooks.

All Biology.

(Including all branches of zoology, botany, physiology, and general biology.)

Complete data for all biology was obtained from twenty-four institutions and partial data from eleven more. Sixteen of these institutions show an increase in the enrollment in biological sciences, eighteen others decreases, while one institution had no change. Five of the Women's Colleges show an increase and five a decrease, three of the latter being found in New England. Two of three southern women's colleges show an increase in enrollment. Institutions gaining are, in order, the northern institutions, the New England men's and coeducational colleges, the western institutions, and the southern institutions. There is a distinct loss in New England women's colleges. While the total enrollment of the institutions considered has increased 63 per cent, the one graph indicates a loss of from 2 to 4 per cent in the enrollment in biological sciences since 1912-13.

The peak years for the biological subjects were during the war,



but since that period, the enrollment has steadily fallen off. The losses would seem to occur in the advanced divisions of the subject, which attract only those students who are preparing for medicine, teaching, forestry, or other professions in which biology is a basic science. Others seem to prefer the constantly growing, semi-biological, non-laboratory social sciences which include the direct application of elementary biological precepts to the affairs of man. Biologists are appearing to make some effort to combat this situation by the formulation of new types of courses, many of them of a non-laboratory or field type. It should be a matter of greater concern to biologists at large that their science does not show a healthier growth.

(*To be continued.*)

CLEVELAND SCHOOLMASTERS' CLUB COMMITTEE REPORT ON SCIENCE.

By Ellis C. Persing,
Chairman Cleveland School of Education.

When your science committee began their work about three years ago, there were a number of problems relating to science instruction which seemed to claim some study.

The committee was convinced that any problem which it should attempt should be for the promotion of a twelve-year science curriculum from the Kindergarten through the High School. After a consideration of the many problems the committee decided to confine their first study to Senior High School science. As you will recall the first study dealt with the general objectives for General Science, Biology, chemistry and physics and indicated that teachers of these sciences were more interested in science as a specialized subject, as shown by the fact that pupils were found to be more familiar with technical terms than the common terms of the subject matter. And further there was a lack of agreement between stated aims and what the pupils are actually learning in these sciences. The results of this work seemed also to indicate that chemistry should come in the later years of the high school course. Furthermore in the organization of the curriculum for the senior high school more consideration should be given to the sequence of the sciences in order that pupils may not graduate from our high schools without an opportunity to learn the phases of science which are necessary for every-day life.

The next year your committee began a study of science in the elementary school and junior high school. The major part of the work was with the junior high school since the American Nature Study Society and The Cleveland Elementary Science Committee were at work on the problems of science in the elementary school. The Nature Study Society has published the results of the study in the First Yearbook. The Cleveland Elementary Science Committee consists of twenty-six persons—principals, teachers and members of the School of Education staff. This committee has undertaken the task of stating objectives in science from the kindergarten through the sixth grade. These objectives have been written in a course of study and tried for more than a year in the Cleveland schools. During this time the committee has worked with the teachers in the field to get their help in revising the course. These suggestions are now being incorporated in the course in elementary science for next year. In addition to this the Cleveland Elementary Science Committee has undertaken a study to determine the objectives in elementary science from a study of pupils' questions.

The complete report of your committee for last year was published in the Journal of Chemical Education Vol. 3, , No. 3, March, 1926. The fact that out of 103 schools answering the questionnaire, fifty-four require science in the seventh year, seventy-one require science in the eighth year and fifty-four require science in the ninth year, indicates that science has become established in the three years of the junior high school. This you will see makes the science course continuous through the elementary school, junior high school and senior high school.

With the work of reorganization going on in the elementary school and the senior high school your committee decided to work on the problem of what science to teach in the three years of the junior high school. Since it would be impossible to complete this study in one year, your committee wishes at this time to submit an outline of procedure for the work which is being carried on in connection with sub-committees.

While the present objectives of junior high school science have been determined by comparatively careful analyses of social needs they are not adequate. Hopkins in Denver analyzed the content of perodicals. Washburne analyzed children's questions. The same procedure was followed by Pollock in Columbus and by Caldwell and Eikenberry.

Your committee proposes to make four parallel studies, the results of which taken together would be an advance over any previous analysis of junior high school objectives in science. The procedure includes first, an analysis of present objectives as given in textbooks, courses of study, and curriculum investigations; second, an analysis of the questions and activities of children; third, an analysis of the questions in science asked by adults; fourth, a systematic analysis of the environment. The objectives obtained in any one study will be checked against the objectives obtained in the other studies. In this way adequate attention will be given to existing materials, pupils' interests and activities, and adult interests. The analysis of the environment should reveal any important elements which have been neglected by the other studies.

SCHOOLMASTERS' CLUB SCIENCE COMMITTEE.

Problem: What are the objectives in science for the Junior High School?

Study I.

(a) Discovering objectives by analysis of courses of study and textbooks.

(b) Stating the objectives from the data of curriculum investigations in science.

Study II.

(a) Determining the interests of pupils by analysis of questions asked by pupils in the Junior High School.

(b) Determining the interests from what pupils actually do.

Study III.

(a) Discovering objectives in science by analysis of questions asked by adults or statements of adults.

(b) Adaptation of Study II for adults.

Study IV.

Discovering objectives by analysis of the environment.

H. P. HARLEY,
CHARLES A. MARPLE,
C. H. SALTER,
HENRY HARAP,
ELLIS C. PERSING, *Chairman.*
Committee.

Teachers in Gilbert School, Winsted, Conn., who have completed 20 years of service and whose salaries are paid in full by the school, are entitled, under a recent resolution of the trustees, to leave of absence with full pay for the next school year. Instead of this, if perferred, they may teach the whole or any part of a year, and receive so much of an additional full year's salary as the number of weeks taught bear to the number of weeks in the school year.

HOME GROWN RUBBER TRIED OUT BY GOVERNMENT EXPERTS.

All the schemes to take a belated stitch in the American rubber dilemma which resulted when Great Britain pulled in her supply are beset by difficulties. One of the least known of these schemes, although not necessarily the most unpromising, is that for growing rubber right here at home, under the semi-tropical sun of Florida and California.

The U. S. Department of Agriculture has been trying out seeds and plants of various rubber-producing species in experimental gardens, but as it takes a long time for the plants to mature and produce latex, officials have as yet no information to give out, and they are advising enthusiastic investors not to put any money as yet into Florida or California rubber.

Botanists name a long list of plants which will produce the milky sap containing rubber. The most important of these today is the Para rubber tree, Hevea guianensis. It grew originally in the Amazon Valley but was bootlegged out more than half a century ago by British planters who tried it out in Kew Gardens, London, and in Ceylon, to see if it would grow outside of Brazil. Then it was used to start the vast plantations in the East Indies that are now supplying the world with most of its rubber.

"Healthy seedlings of the Para rubber tree have been grown at the U. S. plant introduction gardens near Miami, and are being transplanted to different conditions of soil and exposure," Dr. W. A. Taylor, chief of the Bureau of Plant Industry, stated in his annual report to Congress. "The collection of rubber plants now growing at Miami includes altogether about twenty different types.

"Rubber plants that are natives of dry regions are being tested in California, in the coast regions as well as in the interior valleys," he continued. "Several dry-country rubber plants are known in Mexico, while others are reported in South America, Africa, and Madagascar. The production of rubber from the Mexican guayule plant has been investigated by a private corporation and the stage of agricultural practicability is believed to have been reached in California.

"Desert types of rubber plants are being grown in the lower valley of the Colorado River, and the possibilities of one of the common milkweeds are being studied because it grows well on waste lands and produces a large quantity of rubber-bearing material readily and cheaply. Cultivation might extend over large areas if ways of utilizing the substance were perfected.

"This plant is widely scattered in southern Arizona and the desert regions of Sonora and southern California, and it also grows in small ravines and gullies of barren hillsides a few miles from the coast of Lower California. Some of the plants grow so large that they form dense masses more than six feet high and ten feet across."

If any of the rubber-bearing species does show a willingness to produce rubber in the United States in worth while quantities, many economic problems would still have to be solved before rubber growing could be done on a commercial scale.

Para rubber, if that should be chosen, would not have the even rainfall it has in the East Indies because Florida has distinct wet and dry seasons. With even rainfall, rubber trees may be tapped the year around, but with an uneven one, tapping would have to be seasonal. This would involve labor complications, because at certain times a great number of laborers would be needed, and at others only a few.

Even if that problem could be satisfactorily solved by secondary crops, there would still be a labor problem. East Indian rubber planters can

get cheaper labor than Florida or California planters can ever hope to get. Therefore, some other means would have to be found to reduce the cost of producing the rubber in order to compete with England's East Indian product in price.

The research chemist would have to work out new means of getting the rubber out of the latex, certainly a cheaper and better way. In case one or more of the lesser known plants were to be used, for which no method of extraction is now known, a brand new method would have to be developed. On top of it all, the chemists might come along any day with a cheap synthetic rubber that would stretch as far as the best of nature's product.—*Science Service.*

PROBLEM DEPARTMENT.

CONDUCTED BY C. N. MILLS,
Illinois State Normal University

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

SOLUTION OF PROBLEMS.

Note by *Leonard Carlitz* on *Michael Goldberg's* generalization of Problem 888.

The single example that, for any "a",

$$a^5 \equiv a, \text{ mod } 15,$$

whereas the totient of 15, $\phi(15)=8$, shows that the theorem is not exact. The correction to be made is in the use of multiples of ϕ.

In $a \equiv a$, mod s, s must indeed be the product of different primes; $(n-1)$ is a multiple of what is generally called the Cauchy perfected ϕ function. In this case, we may define it as x^s, equal to the least common multiple of

$$(p_1-1),\ (p_2-1),\ \ldots\ldots\ (p_k-1),$$

if $s=p_1p_2p_3\ \ldots\ p_k$.

Thus, $x^{3.5}=$ L. C. M. of 2, 4, $=4$. The proof follows from the fact that, a prime to h,

$$a^{x^h} \equiv 1, \text{ mod } h.$$

921. *Proposed by R. T. McGregor, Elk Grove, Cal.*

The square on the third diagonal of a quadrilateral inscribed in a circle is equal to the sum of the squares of the tangents to the circle from its extremities.

I. *Solved by George Sergent, Tampico, Mexico.*

ABCD is the given quadrilateral, having EF as its third diagonal. EG and EG′ are the tangents from point E, and FH and FH′ are the tangents from point F. It is known that the chord of contact GG′ produced passes through F, and is $\perp$ EO. It is the polar of E. Its intersection, I, with EO, is the conjugate point of E, and we have the relation

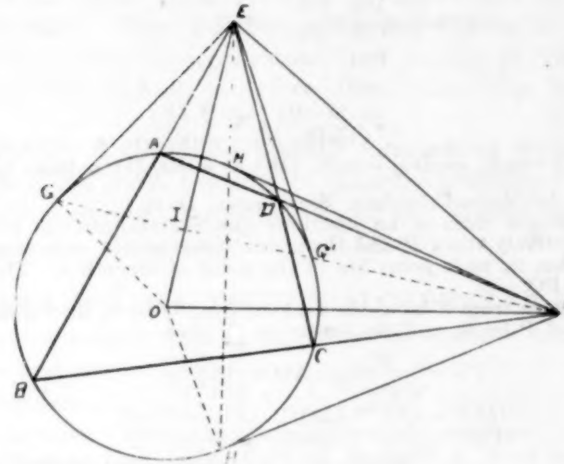
$$(OG)^2=(EO)\cdot(IO)=R^2.$$

In the $\triangle$EFO, $\angle$EOF is acute, and we have

$$\begin{aligned}(EF)^2 &= (EO)^2+(FO)^2-2(EO)\cdot(IO)\\ &= (EO)^2+(FO)^2-2R^2. \qquad (1).\end{aligned}$$

In the right triangles EGO and FHO, we have

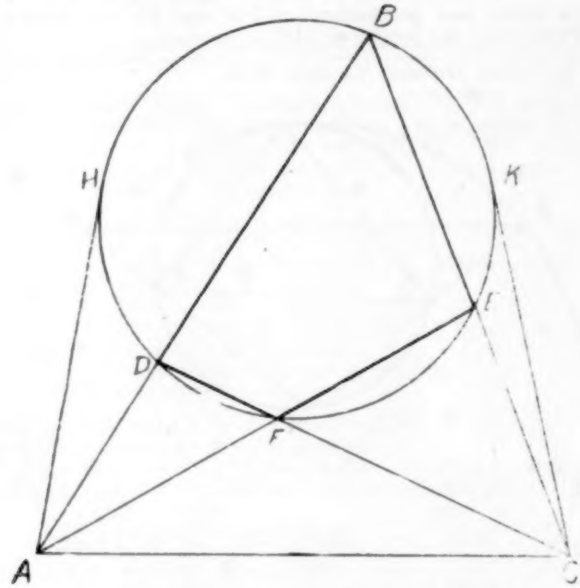
$$(EG)^2=(EO)^2-R^2,$$
$$(FH)^2=(FO)^2-R^2.$$



By addition, $(EG)^2(FH)^2 = (EO)^2 + (FO)^2 - 2R^2$. (2).
Comparing (1) and (2) we get

$$(EF)^2 = (EG)^2 + (FH)^2.$$

II. *Solved by Fred A. Lewis, University, Ala.*



If $(AC)^2 = (AH)^2 + (CK)^2$, we need only to prove that

$$(AC)^2 = (AD) \cdot (AB) + (CE) \cdot (CB).$$

The last statement may be written,

$$(AC)^2 = (AB)\ [(AD) + (DB)] + (CB)\ [(CE) + (EB)] - 2(AB)\ (CB) \cos B.$$

Expanding the terms in the right member we get as a part the expression

$$(DB)\ (AB) + (EB)\ (CB) - 2(AB)\ (CB) \cos B,$$

which we may prove equal to zero.

$$2 \cos B = \frac{DB}{CB} + \frac{EB}{AB}$$
$$= \frac{\sin C}{\sin D} + \frac{\sin A}{\sin E}$$
$$= \frac{\sin(D+B)}{\sin D} + \frac{\sin(B+E)}{\sin E}$$

Since $\sin D = \sin E$, $\cos D = -\cos E$, $(D+E) = 180$, (1) reduces to zero.

III. *Solved by Michael Goldberg, Washington, D. C.*

If the opposite sides of an inscribed quadrilateral meet in points P and Q respectively, then P and Q are conjugate points with respect to the circle, that is, each point lies in the polar of the other. The third diagonal is PQ.

If the tangent from P be a, the tangent from Q be b, the radius be r, the inverse of P be A, and the center be O, then

$$PA = \frac{a^2}{\sqrt{a^2+r^2}}, \quad AO = \frac{r^2}{\sqrt{a^2+r^2}}$$
$$(QA)^2 = (QO)^2 - (AO)^2, \quad (QO)^2 = b^2 + r^2.$$

Hence, $$(PQ)^2 = (PA)^2 + (QA)^2 = a^2 + r^2.$$

Also solved by *F. A. Caldwell, St. Paul, Minn.;* and *Leonard Carlitz, Phila., Pa.*

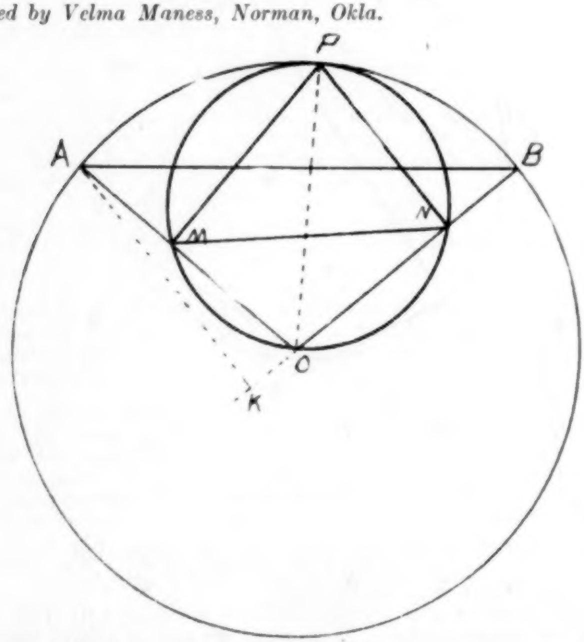
922. *Proposed by J. E. B., Waco, Texas.*

In setting up this problem one term was omitted. The complete statement is given in proposed problem 936.

923. *Selected.*

A and B are two fixed points on a circle whose center is O. P is any point on the circle, and perpendiculars PM and PN are drawn to AO and BO. Prove that the length of MN is constant.

I. *Solved by Velma Maness, Norman, Okla.*



Since A and B are fixed, the angle AOB determined by the radii AO and BO is fixed; and since M and N lie on AO and BO, the angle MON

is the same as angle AOB. The quadrilateral MONP is inscriptible, since PNO and PMO are right angles. Then PO, a radius of the given circle, is the diameter of the circumcircle MONP. The angle MON, or its supplement, will be subtended by MN in circles of equal diameter PO. Therefore, MN is of constant length.

II. *Solved by Michael Goldberg, Washington, D. C.*

The notation refers to the figure for Solution I.

Let $\angle MPN = \theta$, $\angle MPO = \alpha$, $OM = a$, $ON = b$, $MN = c$, then

$$a = r \sin\alpha.$$
$$b = r \sin(\theta - \alpha)$$
$$c^2 = a^2 + b^2 - 2ab \cos(\pi - \theta).$$

Substituting the values of a and b gives

$$c^2 = r^2[\sin^2\theta(\sin^2\alpha + \cos^2\alpha)] = r^2\sin^2\theta.$$

Hence, $MN = c = r \sin \theta =$ a constant.

III. *Solved by Raymond Huck, Shawneetown, Ill.*

The notation refers to Figure for Solution I.

Since the quadrilateral OMPN may be inscribed in a circle, $\angle PMN = \angle POB$. Applying the law of Sines to the triangle MNO,

$$\frac{MN}{\sin \angle AOB} = \frac{ON}{\sin(90^\circ - \angle POB)} = \frac{ON}{\cos \angle POB}.$$

In triangle OPN, $ON = OP \cos \angle POB$. Hence,

$$MN = OP \sin \angle AOB = \text{a constant}.$$

Note by the *Editor*. Since $OP = OA$, and $\sin \angle AOB = \sin \angle AOK$,

$$AK = OA \sin \angle AOK = OP \sin \angle AOB = MN.$$

This means that the length of MN is always equal to the length of the perpendicular from point A to line BO (or from point B to line AO). This fact that MN is a constant is easily derived from the statement that for the inscribed triangle PMN

$$MN = OP \sin \angle MPN = OP \sin \angle AOB.$$

Also solved by *F. A. Caldwell, St. Paul, Minn.; George Sergent, Tampico, Mexico; Charles T. Oergel, State College, Pa.; Leonard Carlitz, Philadelphia, Pa.; C. L. Hunby, Howard Dudley, T. E. N. Eaton, Preston Blair, Redlands, Cal.; Clarence F. Holmes, Elizabeth City, N. C.; Walter C. Carnahan, Bloomington, Ind.;* one solution received with the name of the solver omitted; *R. T. McGregor, Elk Grove, Cal.*

924. *Proposed by Norman Anning, Ann Arbor, Mich.*

Break m^4-6m^2+1 into quadratic factors in three ways.

I. *Solved by Clarence F. Holmes, Elizabeth City, N. C.*

(*a*). By quadratic formula:

$$m^2=3+2\sqrt{2}.$$

Hence the two factors

$$(m^2-3-2\sqrt{2})\ (m^2+3+2\sqrt{2}).$$

(*b*). By separation of $6m^2$:

$$(m^4-2m^2+1)-(4m^2).$$
$$(m^2-2m-1)\ (m^2+2m-1).$$

(*c*). By undetermined coefficients:

Let $m^4-6m^2+1=(m^2+am+b)\ (m^2+cm+d)$. Equating coefficients of like terms we have

$$a+c=0,\ b+ac+d=-6,\ bc+ad=0,\ bd=1.$$

Let $b=d=1$, and solving $a=-2\sqrt{2},\ c=2\sqrt{2}.$

Hence the factors,

$$(m^2-2\sqrt{2}m+1)\ (m^2+2\sqrt{2}m+1).$$

II. *Solved by Leonard Carlitz, Phila., Pa.*

By the quadratic formula we get

$$m^2=3\pm2\sqrt{2}.$$

Hence $\qquad m_k=\pm(1\pm\sqrt{2}),\quad k=1,\ 2,\ 3,\ 4.$

$$m^4-6m^2+1=(m-m_1)\ (m-m_2)\ (m-m_3)\ (m-m_4).$$

Grouping by pairs gives the factors.

Also solved by *Michael Goldberg, Washington, D. C.; Clarence F. Holmes, Elizabeth City, N. C.;* and *F. A. Butter, Jr., San Jose, Cal.*

925. No solutions have been received for this problem. The problem may be too difficult for the High School pupils. The problem is proposed again in this issue, calling for proofs by any method.

PROBLEMS FOR SOLUTION.

936. *Proposed by J. E. B., Waco, Texas.*

Re-statement of 922 with correction.

Find the sum of the infinite series

$$\frac{2}{1\cdot2\cdot3}\cdot\frac{1}{2}+\frac{10}{2\cdot3\cdot4}\cdot\frac{1}{2^2}+\frac{35}{3\cdot4\cdot5}\cdot\frac{1}{2^3}+\frac{102}{4\cdot5\cdot6}\cdot\frac{1}{2^4}+\frac{267}{5\cdot6\cdot7}\cdot\frac{1}{2^5}+\frac{654}{6\cdot7\cdot8}\cdot\frac{1}{2^6}$$

937. *Proposed by J. F. Howard, San Antonio, Texas.*

Problem 925, of the April issue; solutions by any method are desired. Also an elementary solution is desired, which is suitable for *High School Pupils.*

If a circumscribed quadrilateral be formed by drawing tangents at the vertices of an inscribed quadrilateral, the diagonals of the two quadrilaterals are concurrent.

938. *Proposed by W. M. Gaylor, Morris High School, New York City.*

In how many ways may n men take their hats so that each has a hat not his own?

939. *Proposed by Leonard Carlitz, Phila., Pa.*

Three circles, O_1, O_2, O_3, meet in a point P, and O_1 and O_2 meet in A_3, O_2 and O_3 meet in A_1, O_1 and O_3 meet in A_2. If B_1 be any point on O_1, other than A_2, A_3 and P, B_2 being the intersection of B_1A_3 with O_2, B_3 of B_1A_2 with O_3, then B_2, A_1, and B_3 are collinear.

940. *For High School Pupils. Proposed by I. N. Warner, Platteville, Wis.*

A clock gaining three and one-half minutes a day was started right at noon of the 22nd of February: what was the true time when that clock showed noon a week afterward; and, if the clock kept running, when did it next show true time? (From Ray's Higher Arith.)

SCIENCE QUESTIONS.

Conducted by Franklin T. Jones
Supervisor of Training
The White Motor Co., Cleveland, Ohio.

QUESTIONS AND EXAMINATION PAPERS.

479. How much difference exists between the teaching of physics today and twenty years ago?

a. Subject matter;
b. Laboratory work;
c. Method of conducting classes;
d. Demonstrations;
e. Examinations and examination questions;
f. Applicability to daily life;
g. Distinct improvements;
h. Retrogressions—If worse, specify exactly how and where.

The above questions offer opportunity for the readers of this department and for all who are deeply interested in the improvement of science teaching in general to express either their satisfaction or dissatisfaction with present conditions.

Complete Answers Are Not Expected.

Send in your ideas on any one or more of the separate questions. Please be prompt. Do it now!

COLLEGE BOARD EXAMINATIONS—PHYSICS—1906-1926

A comparison of the papers that follow will give some food for thought.

PHYSICS—1906.

Monday, June 18, 1906, 3:45-5:45 p. m.

In this examination 30 counts will be based on the laboratory note book submitted by the candidate and 70 counts on the following questions.

The candidate is to answer seven questions, as indicated below.

A

Answer two questions in this group.

1. A glass tumbler may be filled with water till the surface of the water rounds up above the rim of the glass. Why does not the heaped up water spill over? Mention two other illustrations of the principle involved in your explanation.

2. What is meant by the moment of a force? How is the moment of a force measured? Illustrate the general law of moments by a number of forces in one plane acting upon a body in equilibrium. Give a diagram.

3. Briefly state the law of loss of weight of submerged bodies and the law of displacement of floating bodies.

If the specific gravity of a body be 2.0, how much will a cubic centimeter of it weigh in water? What volume of it will weigh 50 grams in water?

B

Answer two questions in this group.

4. A ball is rolling up a smooth incline at the rate of 15 cm. per second and loses velocity at the rate of 3 cm. per second. How far up the incline will it move before coming to rest?

5. How may the weight of a stick be found by using a single weight, an edge upon which to balance the stick, and a meter rule? Explain your method. Give a diagram.

6. Approximately how deep must a bottle, neck downwards, be sunk in water in order to reduce contained air to half its initial volume? What law of gases applies to the case?

C

Answer two questions in this group.

7. If wind instruments were tuned cold, would the pitch of their tones be too high or too low after they had been warmed by the breath in playing? Give a reason for your answer.

8. Describe a laboratory experiment for determining the amount of heat given out by one gram of steam in changing from steam under normal pressure to water at a temperature of 100°C. What weights should be most carefully taken? Why?

9. A candle flame is 150 cm. from a screen which receives an image four times as wide as the flame itself. If a double convex lens is used to project the image, at what distance from the candle must the lens be placed and what is its focal length?

D

Answer one question from this group.

10. Describe a method of determining the resistance of a battery by means of an ammeter and a set of known resistances.

11. With a diagram and discussion show the advantages of a shunt-wound motor over a series-wound motor.

12. Make a drawing showing a bar electromagnet. Indicate the direction of the current by arrows parallel to the wire, and mark the ends of the bar "N" for north-seeking and "S" for south-seeking poles. Inasmuch as the bar derives all its magnetic strength from the current about it, why is the combination of bar and helix a more powerful magnet than the helix alone?

PHYSICS—1926.

Thursday, June 24, 1926.

Answer ten questions as indicated below. No extra credit will be given for more than ten questions.

Indicate clearly your reasoning in each problem and state the units in which each answer is expressed.

Number and letter each answer to correspond with the questions selected.

PART I.

(Answer all questions in this part.)

1. (a) Why does a body appear to lose weight when submerged in a liquid? (b) Does the amount of weight apparently lost depend upon the volume of the body or upon its weight? (c) Name and state the law governing the apparent loss of weight of a body submerged in any liquid.

2. A wagon weighing 500 pounds was loaded with 1,500 pounds of freight and drawn up an inclined road 1,000 feet long to the top of a hill 50 feet high, the average pull of the team being 400 pounds. (a) Find the total work done by the team. (b) How much of this work was done against gravity? (c) How much was done against friction?

3. A man starts his car from rest and in 8 seconds has acquired a speed of 30 miles per hour. Calculate his acceleration, assuming it to be uniform. At the same rate, how many seconds after starting would he need to pick up a speed of 66 feet per second? Is this acceleration greater or less than that due to gravity?

4. Explain with reference to definite physical principles: (a) Why wet clothes dry more quickly when hung out of doors. (b) Why a cold glass tumbler cracks when plunged into hot water. (c) Why we are uncomfortable on a warm day when the humidity is high. (d) Why in erecting steel buildings the rivets are set when red hot. (e) Why it is difficult to make snowballs on a very cold day.

5. An electric lamp, of the gas-filled type, is found to give 100 candle power when the voltage is 115 and the current is 0.45 amperes. Calculate (a) the resistance of the hot filament, (b) the power used, (c) the rating of the lamp in watts per candle power, and (d) the cost or using the lamp for 1 hour if the charge for electricity is 10 cents per kilowatt hour.

6. (a) What is the difference between a noise and a musical tone? (b) Do sounds of different pitch travel in air with the same speed? Give a reason for your answer. (c) If a flute and a violin produce notes of the same pitch and loudness how can the note from one instrument be distinguished from that of the other?

7. A lamp and a screen are 120 centimeters apart. What must be the focal length of a lens that will produce a real image of the lamp twice as large as the source? Where must the lens be placed?

PART II.

(Answer three questions from this part.)

8. An air tank having a capacity of 10 cubic feet is filled with air under atmospheric pressure of 15 pounds per square inch. What additional volume of air at atmospheric pressure must be forced into the tank in order to raise the pressure to 50 pounds per square inch? Neglect the effect of temperature changes due to compression.

9. From one end of an 8-foot fishing rod which weighs 16 ounces there hangs a fish which weighs 1.5 pounds. The rod is supported in a horizontal position by the right hand at the end of the rod and the left hand 10 inches from the same end. The center of gravity of the rod is 2 feet from this end. What is the direction and magnitude of the force exerted by each hand? (Assume that the hands exert forces vertically.)

10. (a) What is meant by the expression "the heat of fusion of lead is 5.8"? (b) If 60 grams of melted lead at a temperature of 327°C. is poured into 60 grams of water at 10°C., what will be the resulting temperature assuming that no heat is lost? Lead solidifies at 327°C.; its specific heat is 0.03 and its heat of fusion is 5.8.

11. The 120-volt a-c, circuit is to be used to light two 6-volt lamps arranged in series. (a) Show by diagram how this could be done by means of a transformer. (b) What would be the necessary ratio of turns in primary and secondary? (c) If each lamp requires 0.5 amperes to light it properly find the power used by the two lamps. (d) How much current flows in the primary circuit when the two are lighted assuming no loss of power in the transformer?

12. (a) Name an electrical device which will operate satisfactorily on direct current, but not on alternating current. Explain why direct current must be used. (b) Name an electrical device which operates satisfactorily only on alternating current. Explain why the alternating current is necessary. (c) Name an electrical device which may be operated on either alternating or direct current. Explain why either may be used.

13. A man standing in a canyon having parallel walls 5,000 feet apart fires a gun and hears the echo from one wall 4 seconds before he hears the echo from the other wall. How far is he from the nearer wall? (Assume that the temperature is 0°C.):

14. Compare the human eye with the photographic camera by the aid of drawings and discuss two particulars in which they are alike and two in which they are different.

15. With the aid of a labeled diagram show that you understand each of the following terms: (a) Angle of refraction. (b) Principal focus of a lens. (c) Total internal reflection. (d) Critical angle. (e) Dispersion of light.

ANSWERS.

450. *Proposed by R. Beatrice Miller.*

What scheme can be suggested for keeping odds and ends of electric wire in good order?

Answer by W. R. Spiller, Brown Hoisting A Machinery Company.

If the wires can be separated into groups of about the same length they may be kept conveniently in a large shallow box divided into narrow compartments of the different lengths as shown in Fig. 1.

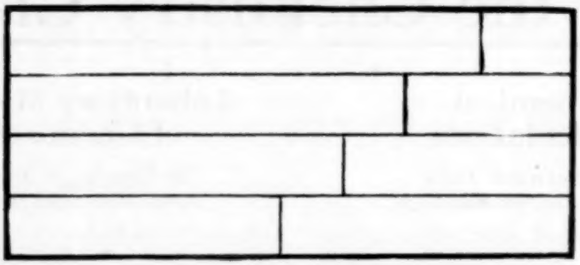


FIG. 1.

For longer wires a series of wall pegs is satisfactory.

Wires that are constantly used in different tests are more easy to handle if spring clips are soldered to the ends. These wires are easy to keep on a wire stretched hoizontally along the wall.

DEPARTMENT OF RESEARCH IN PHYSICS.

The Council and the Educational Committee of The American Physical Society are working on the problem of helping high school and college teachers of physics to advance in their field and to benefit by the work of research physicists. They are recommending a liberal use of this department as one means of attaining their end. Articles will be contributed by members of the Physical Society most of whom are actually engaged in the research work. If physics teachers will write to the editor of this department and tell him of their particular needs, of their interests and, also, of their reaction to the articles that appear, he will be better prepared to present this work to the American Physical Society and to appeal to its members for assistance.

ARTICLES IN CURRENT PERIODICALS.

American Botanist, July, *Joliet, Ill. $1.50 a year, forty cents a copy* Comparative Regeneration of Spinescence in Opuntia and Agave, N. M. Grier. The Meaning of Plant Names—XXVII Caryophyllaceae—2, Willard N. Clute. Spring Flowers, Adella Prescott. The Wall Flower, Lucina H. Lombard. The Indian Pipe, Samuel B. Priest. What is a Common Name? Donald C. Peattie.

American Journal of Botany, July, *Brooklyn Botanic Garden, Lancaster, Pa., $6.00 a year, 75 cents a copy.* Floral Anatomy of Several Species of Plantago, Lena Bondurant Henderson. Some Physiological Considerations of the "Delicious" Apple with Special Reference to the Problem of Alternate Bearing, Emery R. Ranker. Heterothallism in Ascobolus Carbonarius, Edwin M. Betts. A Study of Suction Force by the Simplified Method I. Effect of External Factors, Francis John Molz.

American Mathematical Monthly, May, *Menasha, Wis., $5.00 a year, 60 cents a copy.* Euclidean Variants of Second Degree Curves, C. C. Macduffee, Ohio State University. The Elementary Character of Certain Multiple Integrals Connected with Figures Bounded by Planes and Spheres, Philip Franklin, Massachusetts Institute of Technology. On the Origin of the Term "Root," Solomon Gandz, Rabbi Isaac Elchanan Theological Seminary.

American Naturalist, July-August, *The Science Press, Garrison, N. Y., $5.00 a year, $1.00 a copy.* Variations in Man and Their Evolutionary Significance, Dr. Adolph H. Schultz. The Relation of the Scrotum to Germ Cell Differentiation in Gonad Grafts in the Guinea Pig, Dr. Carl R. Moore, The University of Chicago. Heteroploidy and Somatic Variation in the Dutch Flowering Bulbs, Willem Eduard De Mol. Selection Within a Clone of Helminthasporium Sativum: During Eight Generations, J. W. Miller, During Seven Generations, T. T. Ayres. The Storing Habit of the Columbian Ground Squirrel, Prof. Wm. T. Shaw, Washington State Experiment Station. Crucial Evidence for Antarctic Radiation, Prof. Launcelot Harrison, University of Sydney.

Condor, July-August, *Cooper Ornithological Club, Berkeley, $3.00 a year, 50 cents a copy.* The Migration of the Cackling Goose, Frederick C. Lincoln. Angles and Speculations on Migration, J. T. Nichols. Breeding Birds of a White Mountains Lake, E. A. Goldman. A Report on the Birds of Northwestern Alaska and Regions Adjacent to Bering Strait, Part X, Alfred M. Bailey.

Economic Geography, Clark University, Worcester, Mass., $4.00 a year, $1.00 a copy. The Handicap of Poor Land, Ellsworth Huntington, Yale University. Argentine Trade Developments, Clarence F. Jones, Clark University. Forest Resources of Canada, Roland D. Craig, Forest Engineer Dominion Forest Service. Transhumance in the Sheep Industry of the Salt Lake Region, Langdon White, University of Pittsburg. Oklahoma—An Example of Arrested Development, Charles N. Gould, State Geologist, Oklahoma.

Education, June, *The Palmer Co., Boston, $4.00 a year, 40 cents a copy.* A Plea for Mutual Guidance, F. B. Riggs, Lakeville, Conn. Babbitt Junior and the Small College, H. Guest, Stanford University. Idealism and Pragmatism in Education, Emma L. Antz, Newark, N. J. Agassiz and the Poets, H. G. Good, Ohio University, Athens, Ohio.

Journal of Chemical Education, July, *Rochester, N. Y., $2.00 a year, 35 cents a copy.* Historical Notes upon the Domestic Potash Industry in Early Colonial and Later Times, C. A. Browne. The Commercial Production and Uses of Radium, C. H. Viol. The Value of Oral Examinations, J. A. Muldoon. Paint and Varnish Research at the Bureau of Standards, Percy H. Walker. Forecasting from Aptitude Examination Scores, John D. Clark. Some Unstressed Essentials in Teaching Elementary Chemistry, James H. Walton. A Neglected Opportunity, J. W. E. Glattfeld. A Study of the Comparison of Different Methods of Laboratory Practice on the Basis of Results Obtained on Tests of Certain Classes in High School Chemistry, W. W. Carpenter.

Journal of Geography, May, *2249 Calumet Ave., Chicago, $2.50 a year, 35 cents a copy.* Geography and the Social Sciences, Mendel E. Branom. The Necessity of Accurate Knowledge About Places, Douglas C. Ridgley. The Human Significance of Maturity of a Plains Region, Roderick Peattie. Reflections on the Teaching of Geography, W. S. Dakin.

National Geographic, Washington, D. C., $3.50 a year, 50 cents a copy. July. Standing Iceberg Guard in the North Atlantic, Lieut. Com. F. A. Zeusler. The World's Great Waterfalls, Theodore W. Noyes. Pirate Rivers and Their Prizes, John Oliver La Gorce. August. Through the Great River Trenches of Asia, Joseph F. Rock. The Life of the Moon Jellyfish, William Crowder.

Photo-Era, August, *Wolfeboro, N. Hampshire, $2.50 a year, 25 cents a copy.* Photography on Tour, Roland Gorbold, F. R. P. S. Mountain-Photography Made Easy by Airplane, A. Lewis MacClain. Marketing Pictures, Arthur H. Farrow. Photographing the Yellowstone, Part I, Lloyd W. Dunning. Some Lucky Camera Shots in Death Valley, Loyd Cooper. Photographic Errors, Arthur L. Marble.

Popular Astronomy, June-July, *Northfield, Minn., $4.00 per year, 45 cents a copy.* Swathmore College Eclipse Expedition to Sumatra, John A. Miller. Report on Mars No. 36, Wm. H. Pickering. Astronomical Oculars, Charles S. Hastings. The Clarks, Quoted from a Boston Newspaper article written by Wm. B. Hawkins in 1892.

Scientific American, August, *New York, $4.00 a year, 35 cents a copy.* A Trip to the Bottom of the Sea, Ralph Waldo Miner. Guesswork or Science? The Method by which the Scientist Locates Distant Earthquake Sources is Surprisingly Simple in Principle, Francis A. Tondorf. The Fondest Dreams of the Astronomer, Henry Norris Russell. The Education of a Parachute Jumper, Milton Wright. Giant Floating Aircraft Bases, J. Bernard Walker. Radio and the "Black" Sun, Orrin E. Dunlap, Jr. The Latest Member of our Textile Family, N. A. Parkinson.

Scientific Monthly, July, *The Science Press, New York, $5.00 a year, 50 cents a copy.* The Convergence of Evolution and Fundamentalism, G. T. W. Patrick. What Science Owes the Public, Austin H. Clark. The Present Status of the Theory of Relativity, Dr. Paul R. Heyl. Where Douglas Pioneered, Major John D. Guthrie. Making Airships Safe, Dr. L. B. Tucherman.

School Review, June, *University of Chicago Press, $2.50 a year, 30 cents a copy.* Procedures in Evaluating Extra-Curriculum Activities, George S. Counts. The Life-Career Motive and Its Effect on High School Work, Grayson N. Kefauver. An Investigation of the Scope, Working Practices, and Limitations of Pupil Participation in Government in Secondary Schools, C. R. Dustin. A Statistical Comparison of the Student-Hour Costs of Instruction in Twenty-Two Chicago High Schools, II, D. A. Henry.

BOOKS RECEIVED.

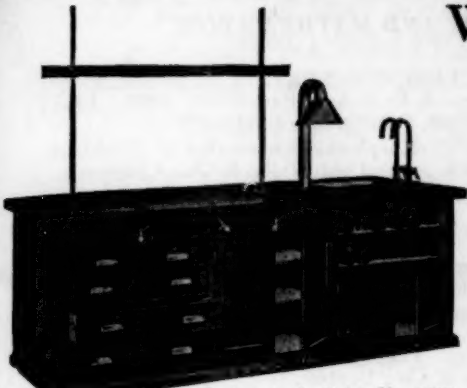
Junior High School Mathematical Essentials Ninth School Year, by J. Andrew Drushel, and J. W. Withers. 14x19 cm. Pages xii+314. 1926. Lyons & Carnahan, Chicago.

A Laboratory Plane Geometry by W. A. Austin, Venice Polytechnic High School, Los Angeles. 15x20 cm. Pages xii+391. 1926. Price $1.40. Scott, Foresman & Co., Chicago.

Algebra by W. R. Langley, Prof. of Mathematics, Yale University and H. B. Marsh, Technical High School, Springfield, Mass. Pages vii+576. 13x18 cm. 1926. The Macmillan Co., New York.

The New Mathematics by John C. Stone. Book One. Pages xii+314. 13.5x18.5 cm. 1926. Price 96 cents. Book Two. Pages x+308. 1926. Benj. H. Sanborn & Co., Chicago.

A Numerical Drill Book on Physics by L. W. Taylor, Prof. of Physics, Oberlin College. Pages v+95. 1926. Price $1. Ginn & Co., Boston, Mass.



Back numbers of School Science, School Mathematics, and School Science and Mathematics may be had for 35 cents a single copy. The Mathematical Supplements for 20 cents a copy. In sets, the prices are, postpaid:

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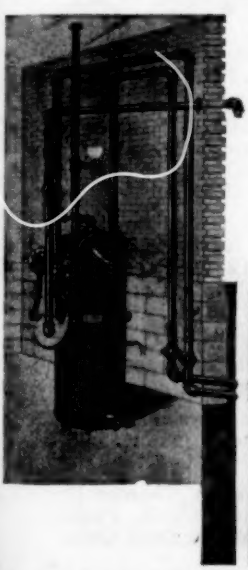

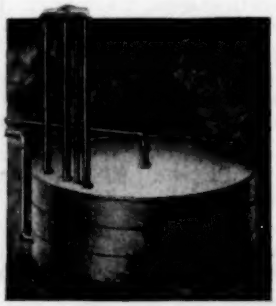

Experimental Science. Heat, Light, Sound Phy. S. E. Brown, Headmaster Collegiate School. Liverpool, England. Pages 530. 1921. 13x19 cm. Price $2.50. University Press, Cambridge, England.

History of Arithmetic by L. C. Karpinski, University of Michigan. Pages xii+200. 13x20 cm. 1925. Rand, McNally & Co., Chicago.

First Lessons in Nature Study by Edith M. Patch, University of Maine. Pages xi+287. 17.5x23.5 cm. 1926. The Macmillan Co., New York, N. Y.

Geology of the Stonington Region, Conn., by Laura H. Martin. Pages 80. 14.5x22.5 cm. 1925. Bulletin State Geological Survey, Hartford, Conn.

Modern Methods in High School Teaching by H. R. Douglas, Prof. of Education, University of Oregon. Pages xviii+544. 13x20 cm. 1926. Price $2.25. Houghton, Mifflin & Co., Boston.

A Brief Course in College Algebra by Walter Burton Ford. Revised Edition. 14x20 cm. Pages vi+288. 1926. The Macmillan Co.

Calculus by H. W. March and H. C. Wolff. 13x19 cm. 1926. Pages ix+398. Price $2.50. McGraw-Hill Book Co., New York.

The Elements of Astronomy by E. A. Fath. 16x24 cm. Pages viii+307. Price $3.00. 1926. McGraw-Hill Book Co., New York.

Comparative Anatomy of Vertebrates, by J. S. Kingsley, Professor of Zoology, Emeritus, University of Illinois. Cloth. Pages x+470. 15x23 cm. Third Edition, Revised. 1926. P. Blakiston's Son & Co. Price $4.00.

A Laboratory Guide for General Botany, by C. Stuart Gager, Director of the Brooklyn Botanic Garden. Third Edition. Cloth. Pages x+205. 13x19 cm. 1926. P. Blakiston's Son & Co. Price $1.25.

The Work of the College Entrance Examination Board, 1901-1925. Cloth. Pages ix+300. 15x23 cm. 1926. Price $4.00. Ginn and Company.

Chemical Calculations, by Bernard Jaffe, Instructor in Chemistry, Jamaica High School, New York City. Cloth. Pages xvi+159. 14x20 cm. 1926. World Book Company, New York. Price $1.28.

Introductory College Chemistry, by Neil E. Gordon, Professor of Chemistry, University of Maryland. Cloth. Pages xiv+688. 15x21 cm. 1926. World Book Company, New York. Price $3.80.

Chemistry and Its Uses, by William McPherson and William Edwards Henderson, Professors of Chemistry, Ohio State University. Cloth. Pages vi+460. 14x19 cm. 1926. Ginn and Company. Price $1.60.

Qualitative Analysis, by William C. Cooper, Professor of Chemistry, DePaul University, Chicago. Cloth. Pages viii+142. 14x20 cm. 1926. World Book Company, New York. Price $1.52.

Elements of General Science, with Experiments, by Otis W. Caldwell, Professor of Education, Columbia University and William L. Eikenberry, Professor of Science, East Stroudsburg State Normal School, Penn. Cloth. Pages xv+600. 14x20 cm. 1926. Ginn and Company. Price $1.68.

Analytic Functions of a Complex Variable, by David Raymond Curtis, Professor of Mathematics, Northwestern University. Cloth. Pages xi+173. 13x19 cm. 1926. Price $2.00. Open Court Publishing Company, Chicago.

The Practice of Teaching in the Secondary School, by Henry C. Morrison, Professor of Education, University of Chicago, Cloth. Pages viii+661. 16x23 cm. The University of Chicago Press, Chicago.

Intermediate Light, by R. A. Houstoun, Lecturer on Physical Optics, University of Glasgow. Cloth. Pages x+228. 13x19 cm. Price $1.75. Longmans, Green & Co., New York City.

Health Through Prevention and Control of Diseases, by Thomas D. Wood and Hugh Grant Rowell of Columbia University. Cloth. Pages vi+122. 14x20 cm. Price $1.00. December, 1925. World Book Company, New York City.

The Science of Things About Us, by Charles E. Rush, Librarian of the Indianapolis Public Library and Amy Winslow, Chief of the Technology Division of the Indianapolis Public Library. Pages ix+318. 12.5x19 cm. Cloth, 1926. Price 90 cents. Little, Brown and Company.

Open Doors to Science with Experiments by Oris W. Caldwell, The Lincoln School of Teachers College, Columbia University, and W. H. D. Meier, State Normal School, Framingham, Mass. Pages ix+416. 13x19 cm. Cloth 1926. Ginn and Company.

How to Teach General Science by J. O. Frank, Wisconsin State Normal School. Pages xii+240. 13x19.5 cm. Cloth. 1926. Price $2.00. P. Blakiston's Son & Co.

A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools by Francis D. Curtis, University of Michigan. Pages xvii+341. 13x19.5 cm. Cloth. 1926. Price $2.50. P. Blakiston's Son & Co.

BOOK REVIEWS.

Introductory College Chemistry, by Neil E. Gordon, Professor of Chemistry, University of Maryland. First edition. pp. xiv+668. 15x21x3 cm. Illustrated. Cloth. June, 1926. $3.80. World Book Co., 2126 Prairie Ave., Chicago, Ill.

Here at last we have a college text that shows not only marked originality of treatment but a method of attack that has been proving successful in secondary school teaching of chemistry and that cannot fail to arouse more interest on the part of the college student than he has shown in the past when subjected to the cut and dried, systematic, presentation of chemistry that has been so much in evidence.

The author has been a leader in the field of chemical education and is at present Chairman of the Division of Chemical Education, Head of the Senate of Chemical Education and Editor of the Journal of Chemical Education of the American Chemical Society. This work is the product of much thought and study on the subject of the method of teaching chemistry and has back of it a wide range of experience in the actual trial of the method with mimiographed sheets, upon many classes. Quoting from the preface "The idea that interest must precede attention and learning, the principle of self-activity and the supplying of the pupil with material that allows him in large part to complete his work without interference from the teacher, the individual method of instruction, the Dalton plan, the project method and project philosophy, and the unit study idea of organizing material have worked a mighty change in our elementary and high school instruction, and to the author it seems that they must have a great effect upon our college teaching." The text contains also the laboratory manual so that the progress of the work may be built up around the laboratory work, which is a most natural method. The material "is broken up into definite short units" "In accordance with the project and unit study ideas." "In the use of the atomic number system of classification, and in the explanation of chemical properties and reactions in terms of electrons, the text goes somewhat beyond those to which we have been accustomed." This is as it should be for it is time someone put into text book form the essentials of the newer ideas as to sub atomic structure which have hitherto been kept "on ice" so to speak, in the literature, where the undergraduate seldom penetrates to find them.

The study of the metals in Part II also shows originality of treatment. While the metals are studied in periodic arrangement the analytical reactions, are placed in sections at the ends of the different "Books" so that the analytical portions may be omitted leaving a brief descriptive text on the metals.

The table of contents, which follows, shows something of the order of treatment: Book One—Water, Book Two—Some Fundamentals of Chemistry (Chemical Laws, Gas Laws, Molecular & Atomic Weights, Symbols & Formulas, Nomenclature; Valence, Chemical Equations and Calculations.) Book Three—The Atmosphere, Book Four—Acids,

Bases and Salts, Book Five—The Oxygen-Sulphur Family, Book Six—The Halogen Family, Book Seven—The Classification of the Elements, Book Eight—The Carbon Family, Book Nine—The Nitrogen Family, Book Ten—Colloidal Chemistry. Then comes Part II containing eight books on the metals arranged according to the periodic classification. Every college teacher of chemistry must see this new text. F. B. W.

Rich's Chemistry Tests, with manual for Giving and Scoring, by S. G. Rich, published by the Public School Publishing Co., of Bloomington, Ill. Copyright, 1923.

There are two forms, the gamma and the epsilon. They are of similar difficulty but afford alternative forms. The first page, as is usual in such tests, carries the instructions and sample questions and answers. There are 25 questions in each test and the answers to each question as supplied are four in number, three of them false, the other true. The time allotted for answering the 25 questions is 25 minutes.

We have here in convenient printed form a well selected set of questions for use in testing achievement of our pupils in chemistry. While much of that which is tested is of informational character only, yet there is a certain value in thus testing chemistry pupils and the Rich tests can be recommended for this purpose.

Special features of the Rich tests are (1) The *norms for every quarter-year* of instruction, thus permitting measurement at all stages instead of as a "post-mortem" only. (2) The content: all *within* existing courses, but sifted to include only items for which there is some evidence that they serve any educational purpose. No other test has this feature. (3) The "mental content"—one-third of the questions involve thinking. No other standardized tests approach this extent of non-memory content. (4) The inclusion of "modern chemistry" content, as in the question on gas-masks, that on colloid solution, etc.—so that the teacher who gives a strongly modern course does not have his pupils' results shown too low. (5) The *definite* and *full* directions for giving and scoring. F. B. W.

Chemical Calculations, by Bernard Jaffe, Instructor in Chemistry, Jamaica High School, New York City. In New World Science Series, e[illegible]ed by John W. Ritchie. Cloth. xvi+159 pages. Price $1.28. Y[illegible]-on-Hudson, New York; World Book Company.

This book is designed to strengthen the instruction in che[illegible]y in secondary schools and first year college where it has been shown [illegible]o be lamentably weak in chemical arithmetic.

With this book, teachers will be able to give students of general chemistry a thorough training in chemical calculations. It develops a method of attack on problems by classifying them according to types, explaining the method of solution, and giving numerous examples after each new step has been presented. Moreover, it furnishes that abundance of problem material which most textbooks on elementary chemistry lack. There are over a thousand problems to meet all the required needs of high school and first year college classes.

Chemical Calculations can be used with any of the recent textbooks and a teacher should find it well worth the price when it is placed in the hands of his students. F. B. W.

Chemistry and its Uses, a Text Book for Secondary Schools, by William McPherson and William Edwards Henderson, Professors of Chemistry, Ohio State University. Revised Edition. pp. viii plus 460. 14x19 1-2x 2 1-2 cm. Illustrated. Cloth. 1926. $1.60. Ginn & Co.

Lest some conservative teacher, considering the title of this text, should fear that the authors have fallen from grace, we may quote from the preface these reassuring words,—"The main object of the course in chemistry must always be *to train young people to think and to imagine in the realm of chemical facts and laws* and the teacher who finds at the end of the course that his pupil has acquired what seems to be a fund of useful information, but has little ability to think for himself how he would solve a simple chemical problem, should feel dissatisfied with his effort. The italics are the authors". Thus it may be seen that the revised

text is quite orthodox in its teachings. Though the picture is the original classic the frame is quite new. A successful effort has been made to stress the applications of chemistry while teaching the facts and laws and principles. There is also something of an attempt to call to the attention of the pupil some of the opportunities that lie in the field of chemistry. While it is to be hoped that this will not result in a too general flocking into the profession of chemistry, nevertheless it would be well if a bit more of vocational guidance were made available to our pupils.

Among the newer features of the text we note a short but interesting chapter on foods in which the vitamins come in for some attention, a chapter on colloids, a very interesting "Story of radium," an elementary discussion of atomic structure and a bibliography for the chemical library. All high school teachers of chemistry will be interested to see this text.

F. B. W.

Qualitative Analysis, by William C. Cooper, M. S., Ph. D. Professor of Chemistry, De Paul University, Chicago, Ill. First edition. pp. viii+142. 14.5x20.5x2 cm. Cloth, 1926. $1.52. World Book Co.

A laboratory manual for college classes in qualitative analysis. Brief sections explaining the reasons for the procedure follow the various parts of the book. Equations are absent except that molecular equations are used in the brief outlines in the back of the book. It is explained in the preface that it is assumed that those who use the manual have had a good course in general inorganic chemistry. Still, one misses his ions—and wonders if students will apply what they have been exposed to, sufficiently to comprehend what it is all about.

The directions are clear and concise. F. B. W.

Applied Physics, W. D. Henderson, University of Michigan. Pages 82. 20 1-2x28 cm. Paper. 1924. Lyons & Carnahan, Chicago.

This book, coming from the pen of this splendid instructor, cannot help but be one of the most practical and up-to-date laboratory manuals that have come from the press in a long time.

The object of the book has been to provide a series of greater laboratory exercises in secondary school physics, and also designed to be used with inexpensive apparatus. It gives to the pupil the fundamental experience in teaching him the right methods to proceed in order to attain a good working knowledge of physics.

The writer can recommend this laboratory manual in every respect.

C. H. S.

Life and Evolution; an Introduction to General Biology. By S. J. Holmes, Professor of Zoölogy in the University of California. iv+449 pp., 227 figs., New York, Harcourt Brace and Co. 1926.

This new book represents a radical departure from the older type of college text in general biology. The newer aspects of zoölogy and botany are adequately reviewed. It treats biological principles, as illustrated by both animal and plant forms, in a manner that should appeal to the interests of the general student and at the same time give the beginning special student a foundation in the fundamentals of the life sciences. While the book is intended for use in class work, yet its style and organization are such as make it suitable for general reading. It will prove especially helpful to the general reader or student who desires to make an intelligent study of the subject of organic evolution. The book should be in the hands of teachers of the biological sciences in the high schools, as a reference. Lists of references at the end of each chapter and a glossary add much to the value of the book. The work is well printed and illustrated, but it is to be regretted that it is rather poorly bound. J. C. I.

Biology for Beginners. Revised Edition. By Truman J. Moon, Middleton, N. Y. High School. vi+647 pp.+xvii, 206 figs. 1926.

This text furnishes an abundance of material to serve as a basis for a year in general biology in the high school. The author seems to adhere throughout the text to the general principle stated in the preface that a text book for beginners must make clear-cut statements and sharp distinctions. In general, this has worked out successfully. It seems to this reader, however, that the idea has been carried rather too far in some

instances. Simplifying the explanation for osmosis makes it misleading. An accurate notion of the process could be developed as easily. Probably the author expects the instructor and collateral reading cited to supply the missing detail. The book is exceptionally strong in pedagogic devices. A vocabulary at the beginning of each chapter gives the meaning of biological terms which are used for the first time in the chapter. Numerous tables are used in making comparisons and stating facts in concise form. An outline of the context is given at the end of each chapter. Definite references for collateral reading are also given at the end of each chapter. The pictures, diagrams, and sketches used throughout the text are excellent. The work as presented is readable and teachable. J. C. I.

Modern Methods of Teaching Arithmetic, by Ralph S. Newcomb, Professor of Mathematics and Vice-President of the East Central State Teachers College, Ada, Oklahoma. 19x13.5 cm. pp. xv+353. 1926. Houghton Mifflin Co. Price $2.00.

This book discusses the teaching of arithmetic from the modern point of view. There are eighteen chapters devoted to such topics as the history of arithmetic, the psychology of arithmetic socialization and correlation of arithmetic, drill in arithmetic, the recitation, teaching the fundamental operations, fractions and percentage, measuring ability, problem solving, and tables, statistics, and graphs. Following each chapter is an extensive bibliography.

The book is well written and should interest both teachers of elementary and secondary mathematics. J. M. Kinney.

Plane Geometry Based on Observation and Experiment, by John O. Pyle, Teacher of Mathematics in the Carter H. Harrison Technical High School, Chicago. pp. xi+300. 20x13 cm. 1926. P. Blakiston's Son & Co. Philadelphia.

This is a second preliminary edition revised and reorganized.

The author treats the subject matter of geometry in a way which is quite similar to that in which the natural sciences are treated. He believes the course in geometry should rest upon and grow out of the experiences of the pupils.

Teachers of geometry should examine this book. It does not look like the model secondary geometry. J. M. Kinney.

Elementary Mathematical Analysis, by Charles S. Slichter, Professor of Applied Mathematics. University of Wisconsin, with additons and Revisions by Warren Weaver, Associate Professor of Mathematics, University of Wisconsin. 1925. 19x13.5 cm. McGraw-Hill Book Co., New York.

This is the third edition of a book that has been used since 1914 as a text for college freshmen. It was one of the pioneers in presenting the subject matter of college freshman mathematics, organized about the notion of functionality. The functions about which the material is organized are: (1) The Power Function, $y=ax^n$; (2) The simple Periodic Function, $y=a$ sin nx; (3) The Exponential Functions.

J. M. Kinney.

College Algebra, by W. L. Hart, Ph. D., Professor Mathematics in the University of Minnesota. 14.5x20.5 cm. pp. viii+360. 1926. D. C. Heath & Co.

This book is attractively written and contains an abundance of material. It includes such topics as the mathematics of investment, infinite series, and partial fractions. Problems are numerous. J. M. Kinney.

Standard Service Arithmetics, Book Two, for grades five and six, by F. B. Knight, G. M. Ruch, College of Education University of Iowa, and J. W. Studebaker, Superintendent of Schools, Des Moines, Iowa. 14.5x19 cm. pp. xvi+547. 1926. Price $0.96. Chicago: Scott, Foresman and Co.

This is the first of the forthcoming Standard Service Arithmetics. Books I and III are announced for publication within a year.

The outstanding feature of the text is the abundance of well-distributed scientifically standardized drills which it contains. These include fifty-nine self-testing drills and thirty-eight problem scales. The self-testing drills provide practice on the fundamentals at frequent intervals through-

out the year's work. Problems and examples are arranged in order of ascending difficulty. The standards based on percental ratings are placed at the end of each drill. A "progress chart" enables the pupil to keep a graph record of his achievement. In the problem scales the examples are arranged in order of ascending difficulty with a value attached to each problem and standards placed at the end of each scale.

Careful effort has been made by the authors to make the book as informal as possible. The vocabulary has been strictly limited to that of the child; the significance of each new type of work is carefully and fully explained; attention-getting "sign posts" mark important sections.

A responsible, self-reliant attitude on the part of the pupil is encouraged by means of self-ratings, checking of answers, and informal discussions of the reasons for the work and the results to be expected.

J. M. Kinney.

A Geometry Reader, by Julius J. H. Hayn, Head of Mathematics Department, Masten Park High School, Buffalo, N. Y. 14x20 cm. pp 320. Cloth. Price $1.80. The Bruce Publishing Co., Milwaukee, Wis.

In order to utilize the pupil's recently acquired algebraic knowledge the author presents an interesting introduction which involves computation of areas of triangles, the Pythagorean formula, computations of altitudes, medians, etc., from given data. He also includes in the introduction the fundamental constructions. Also in his "wanton recklessness" he initiates the young student into the mysterious theory of limits and the area of a circle.

Book I deals with parallel lines and angles followed by the theorems on congruency of triangles.

The author's aim is to present the subject matter in the order which is best adapted to the child mind. "The idea is not to shoot correct and careful reasoning into the pupil's head, but to develop this power naturally and pleasantly."

J. M. Kinney.

Open Doors to Science, with Experiments by Otis W. Caldwell of The Lincoln School of Teachers College and W. H. D. Meier, State Normal School, Framingham, Mass. Pages xi+416, Ginn and Co., Boston, Mass.

This text book is a revision of the 1925 edition of the same book with the addition of many new experiments and demonstrations, several new illustrations and considerable new material.

Practical and thought-provoking questions are given at the beginning of each chapter. Additional problems or "Things to Do" are found at the end of each chapter.

This book supplies material for the general science classes in the seventh or eighth grades. The subject matter is based on the school, home and community life of the pupils. "It attempts to keep the habit of inquiry alive and operating." The book is unusually well illustrated, containing many diagrams, photographs, etc., that require further study and analysis by the pupils in order to comprehend their full meaning.

This attempt to supply a textbook for science classes in the lower grades is to be commended. Every teacher should examine this book thoroughly before accepting any other.

I. C. D.

The Science of Things About Us by Charles E. Rush and Amy Winslow of the Indianapolis Public Library. Pages ix+318, $.90. Little, Brown and Co., Boston, Mass.

This very interesting and stimulating book is to be used as a reader for the science classes of the Junior High School Grades. It answers the questions pupils ask. It is written in a simple, direct style and is well illustrated.

"In The Schoolroom," "The House I Live In," "In The Kitchen," 'In The Basement and Laundry," "In The Bathroom," "In The Dining Room," "In The Living Room," "In The Sewing Room," "In the Wardrobe," 'In The Jewel Box" are the ten parts into which the book is divided. There is sufficient information given in each part to enable pupils to understand and appreciate the everyday happenings in their environment.

This reader is deserving of a high ranking in our list of science books and it is hoped every child will be given an opportunity to read it.

I. C. D.